St. John's University
St. John's Scholar

Theses and Dissertations

2024

EXPLORING SCIENCE AND MATHEMATICS TEACHERS' PROFESSIONAL IDENTITY DEVELOPMENT DURING ARTS INTEGRATION PROCESSES

Lulu Sun

Follow this and additional works at: https://scholar.stjohns.edu/theses_dissertations

 Part of the Education Commons

EXPLORING SCIENCE AND MATHEMATICS TEACHERS' PROFESSIONAL IDENTITY DEVELOPMENT DURING ARTS INTEGRATION PROCESSES

A dissertation submitted in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

to the faculty of the

DEPARTMENT OF CURRICULUM AND INSTRUCTION

of

THE SCHOOL OF EDUCATION

at

ST. JOHN'S UNIVERSITY
New York
by
Lulu Sun

Date Submitted November 8th, 2023 Date Approved January 31st, 2024

Lulu Sun	Dr. Elena Jurasaite-O'Keefe

© Copyright by Lulu Sun 2024
All Rights Reserved

ABSTRACT

EXPLORING SCIENCE AND MATHEMATICS TEACHERS' PROFESSIONAL IDENTITY DEVELOPMENT DURING ARTS INTEGRATION PROCESSES

Lulu Sun

Currently, studies on STEAM education or arts integration focus on students' experiences rather than teachers' challenges. Thus, the purpose of this dissertation is to set an example for policymakers, educators, and researchers, to provide better support for art-integrated mathematics and biology teachers by understanding their professional identities growth and their informal art learning. In this qualitative study, I employ case study as my research methodology by conducting interviews, observation, and physical artifacts. My sample consists of a high school mathematics teacher and a biology teacher who bring art to the teaching. My research findings highlight the significance of artistic thinking for art-integrated teachers' teaching. The implications of the study indicate that art-integrated teachers' artistic thinking can be stimulated by enjoying art and expanding the comprehension of art rather than only depending on art specialists.

Keywords: art-integrated teachers, the math teacher, the biology teacher, the art teacher, teachers' professional identity, case study, artistic thinking.

DEDICATION

I would like to dedicate this dissertation to my daughter Xifei, hope you will find your own path during the unceasing journey of learning.

ACKNOWLEDGMENTS

I would like to give my appreciation to my father Professor Sun, I never gave up pursuing my Ph.D. because of your encouragement and the power of a role model. Next, I would like to acknowledge my mother, Ms. Wang, thank you for being there for me all the time.

To my mentors, Dr. Jurasaite-O'Keefe, thank you for being patient and supporting me during this two-year dissertation journey; Dr. Abrams, thank you for telling me to keep chasing my passion. Dr. Ness and Dr. Rosenberg, thank you for advising and helping me in bringing this research to life. Thank you all! I could not have done this without your guidance

Lastly, I would like to be grateful to my doctoral colleague and my best friend Ms. Smith, and my dear friend Mr. Angelopoulos, I cannot express my gratitude with words, all the love, laughter, and patience. Thank you, I made it!

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

> To develop a complete mind: Study the science of art; Study the art of science. Develop your senses – especially learn how to see. Realize that everything connects to everything else. (Leonardo da Vinci)

As an art-science combination master, da Vinci integrated art and science to develop his mind and senses as a scientist and an artist in the High Renaissance era (around 1495-1520), who claimed that "everything connects to everything else" (use APA). Approximately five hundreds of years later, in 2006, Georgette Yakman brought the idea of STEAM into education connecting science, technology, engineering, art, and mathematics. Many schools adopted the idea of art and science integration and started implementing a STEAM curriculum that grew from a STEM curriculum (science, technology, engineering, and math). As a new member, art joins in STEM playing a unique role of integration with other non-art subjects. Some researchers called arts integration with non-art subjects "art fusion" (Wells & Wagner, 2013). Numerous STEAM and arts integration researchers focus on analyzing students' performance in the STEAM or arts integration classes or programs (Davis, 2010; Grant & Patterson, 2016; Hunter-Doniger & Sydow, 2016; Trimble, 2019; Wells & Wagner, 2013; Wylder et.al., 2015). However, only a few studies focus on how non-art subjects' teachers learn art and develop themselves during their arts-integrated teaching experiences (Bequette & Bequette, 2015; Wynn & Harris, 2015). During the arts integration process, STEM subject teachers need to learn how to use art as a new-to-them approach to teaching science and mathematics. Thus, they become art learners and developers of new pedagogies as they integrate art into their

teaching (Jonelle et.al., 2011, 2014; Land, 2013; Reck & Wald, 2018; Snyder et al., 2014). As learners, teachers are learning in various ways and places. Some teachers are learning from peers in informal ways (Hoekstra et. al., 2009; Jones & Dexter, 2014). Some teachers are learning from social media platforms as informal learning spaces (Rehm & Notten, 2016). Jurasaite-O'Keefe's (2022) study emphasized the importance of informal teacher learning by exploring teachers' learning in the workplace and defined teachers' informal learning using five criteria: a) dispositions, b) focus, c) reaction, d) sources, and e) process.

Teachers' informal learning is important for my dissertation, which examines STEM teachers' (especially science and mathematics teachers in this dissertation) different ways of learning arts as they have limited to opportunities to get formal training in arts. Not surprisingly, STEM teachers are transiting from STEM to STEAM or arts integration using informal learning. Therefore, this research explores science and mathematics teachers' informal learning and arts integration experiences during this transition. As teachers experience art learning and its integration, their professional identity changes to include a new role of an art integration teacher. Thus, this dissertation also focuses on exploring teachers' identity development. Finding science and mathematics teachers' development of professional identity trajectories can help the researcher to understand how their roles change: from STEM to arts integration teachers, and from teachers to learners. Moreover, it is important for educators and policymakers to understand science and mathematics teachers' needs during their art-integrated teaching and their informal learning. This understanding "can be used to improve collaborative professional development trajectories as well as to advance the workplace as a context for teacher learning" (Jurasaite-Harbison &

Rex, 2013, p. 2). Educators and policymakers would realize how to support science and mathematics teachers during their arts integration.

As Vygotsky (1978) argued, learning of one thing stimulates learning of other unrelated things. Arts learning will stimulate STEM learning; developing teachers' art-integrated teaching will facilitate STEM education. Arts and STEM, these two "unrelated" contents can support each other in learning. Therefore, arts integration can influence success of teaching STEM.

Along with teachers' learning to integrate arts while teaching in the STEM area, there is another aspect of and the reason for this integration, which is students' success ignited by the arts integration processes. Although it is a very important part of the integration problem, my study focuses on teachers' professional identity growth, and my research was designed and conducted for teachers instead of students. Moreover, it was very difficult to observe and interview both students and teachers in the meantime. Hence, I kept my concentration on teachers rather than measuring students' success.

Definition of Terms

The Art

Traditional categories within the arts include literature (including poetry, drama, story, and so on), the visual arts that includes the graphic arts (painting, drawing, design, and other forms express on flat surfaces), and the plastics arts (sculpture, modeling), the decorative arts (enamelwork, furniture design, mosaic, etc.), the performing arts (theater, dance, music), music (as composition), and architecture (often including interior design) (Encyclopedia Britannica, 2023).

Visual Arts

Two- and three-dimensional art making, including painting, drawing, sculpture,

and art appreciation (Encyclopedia Britannica, 2023; Ewing, 2010).

STEM

In full Science, Technology, Engineering, and Mathematics fields and curriculum centred on education. The STEM acronym was introduced in 2001 by scientific administrators at the U.S. National Science Foundation (NSF) (Hallinen, 2021).

STEAM Education

STEAM education is an acronym for Science, Technology, Engineering, Arts, Mathematics, and used as an interdisciplinary or transdisciplinary approach to teaching and learning that combines the disciplines in a defined learning context (Perignat & Katz-Bunonincontro, 2019).

Arts Integration

Arts integration in STEM is a pre-stage of STEAM (Bequette & Bequette, 2015; Green et al., 2018).

Background: Context and Relevance

This dissertation studies science and mathematics teachers in the STEM field who are implementing arts integration particularly and explores their professional identities' development. During the arts integration process, teachers need to learn how to use art as a new approach to teach science and mathematics. They become learners in this process and move back at forth between being learners and performing their roles as teachers. This special process of learning and teaching potentially develops science and mathematics teachers' professional identity. Therefore, this study discusses how teachers' professional identity changes (if at all), and how the various professional identities emerge during art integration.

Problem Statement

According to Ewing (2010), it is challenging when teachers are not feeling competent to integrate art into their curriculum. Ewing (2010) listed seven reasons for the uneasy relationship between arts and other subjects, teachers' "lack of confidence or expertise with particular or all art forms" and "the misconceptions or baggage from their own prior art experiences" (p. 5) being two important ones among these reasons.

To deeply understand STEM teachers' challenges and diffidence in arts integration, one must know their preparation and professional development for art integration teaching. Researchers found that only a handful of art-integrated STEM teachers are prepared to include arts by implementing certain arts programs, workshops, or models (Jonelle et.al., 2011, 2014; Land, 2013; Reck & Wald, 2018; Snyder et al., 2014). However, countless art-integrating teachers do not receive any formal art preparation. Consequently, teachers become informal learners while they do not receive enough art education to support their arts-integrated teaching. Therefore, it is important to examine these science and mathematics teachers' arts integration preparation, and their informal learning experiences.

Purpose Statement

In response to the lack of teachers' formal arts preparation, the purpose of this dissertation is to examine how mathematics and science teachers' professional identities develop during arts integration to issue recommendations for supporting this development and their professional growth. The pathways to their professional identities' growth could be discovered by analyzing these teachers' stories of art application. Findings from this analysis will offer the policymakers, educators, and research community a systematic approach to how to provide art education

opportunities to teachers.

Rationale for the Study

My dissertation explores science and mathematics teachers' professional identities in the STEM field as they implement arts integration particularly. During the arts integration process, teachers need to learn how to use arts as a new approach to teach science and mathematics. Science and mathematics teachers' professional identity is inherently growing in the process of arts integration. Hence, my study explores how teachers' different professional identities emerge, and how teachers' professional identities shift during art integration.

Research Questions

To explore arts-integrated science and mathematics teachers' professional identities' development during arts-integrated teaching, this dissertation explores:

1. How do (certain) science and mathematics teachers integrate arts into their teaching?
    a. How do science and mathematics teachers' personal experiences and background influence their arts-integration teaching (if at all)?
    b. What do science and mathematics teachers think an arts-integrated science and mathematics teacher should know and teach?

To explore arts-integrated science and mathematics teachers' sub-identities in professional identity development, this study explores:

2. What are art-integrated science and mathematics teachers' sub-identities?
    a. What is the relationship between their sub-identities and arts?
    b. How do their sub-identities interact with their professional identities?

CHAPTER 2 LITERATURE REVIEW

Introduction

In this literature review, I examine extant studies that focus on STEM teachers' arts-integrated teaching, which includes their preparation for teaching and professional development for instruction. To understand teachers' preparation and professional development, one must review how teachers become learners when they do not receive enough art education to support their arts integration in teaching. By doing so, I discuss the reasons for teachers' various preparation and different stages of their professional identity development during learning and teaching. At the same time, examining studies on STEM teachers' arts integration implementation reflects their preparation and art learning, and its impact on their professional identity development.

To search academic articles in English, I used keywords "arts-integrated STEM teachers' preparation" and "STEAM teachers' preparation". All these articles include qualitative, quantitative, and mixed methodology studies. I narrowed down articles' searching range by excluding articles with keywords such as "music," "performing arts," "pre-school," "kindergarten," "literacy," "culture," and "language". In other words, the articles which focus on non-visual arts and pre-school education are excluded from this review. This research focuses on the visual arts; thus, the other forms of arts have been eliminated from the search. Since this study discusses arts integration in STEM, especially in science and mathematics, preschool research, which is a fusion of all subjects, thus, preschools' research has been eliminated too. Furthermore, I selected articles that are most related to my research, such as articles with keywords "arts integration," "STEM," "science," "mathematics/math," "STEAM

education," and so forth. The following step was reading selected articles from, but not limited to, ProQuest, JSTOR, and EBSCO. By following this way, the search results reduced from 95 to 14 for "arts-integrated STEM teachers' preparation", and from 49 to16 for STEAM teachers' preparation".

STEAM Education and Arts-integrated STEM Teachers' Preparation for Teaching

According to STEM School (2022), the development of STEM traces down to 1862, when the Morrill Act of 1862 promoted agricultural science by creating land-grant colleges. The Act has built engineering programs too. STEM training spread out education across land grant institutions the number of which kept growing. In 2001, National Science Foundation (NSF) invented the acronym SMET to represent Science, Mathematics, Engineering, and Technology, which they changed to the acronym STEM in the same year.

In 2006, the researcher Georgette Yakman first developed the idea of STEAM in education by following her belief in innovation and creativity, and she started to implement a curriculum of STEAM in 2007. By January 2019, around 3000 teachers had been involved in the STEAM pedagogy training (Flocchini, 2022).

To study arts-integrated STEM and STEAM teachers' preparation, it is important to clarify the definition of "arts integration" and "STEAM." Silverstein and Layne (2010) defined arts integration as "an approach to teaching in which students construct and demonstrate understanding through an art form. Students engage in a creative process that connects an art form and another subject area and meets evolving objectives in both" (p. 1).

The term "art form" refers to "any branch of creative work in the arts (visual arts,

dance, drama, music); the products of creative work" (p. 3), and the "approach to teaching" emphasizes ways of teaching instead of the content of teaching.

Numerous researchers explored arts integration in teachers' preparation by implementing certain arts programs, workshops, or models (Land, 2013; Pool et.al., 2011; 2014; Reck & Snyder et al., 2014; Wald, 2018). These studies examined existing programs or models that supported teachers' arts integration. When teachers are supported by arts education models, they do not lack art education during the arts integration process. For instance, Pool et.al. (2011) employed the Artful Learning™ model (experience, inquire, create, reflect) in arts-based integration of K-12 mathematical teaching, and they designed instruction of the Artful Learning™ model to prepare teachers for integrative teaching. Snyder et al. (2014) used the SAILSS (the Supporting Arts Integration Learning for Student Success) model to develop a School Improvement plan for teaching an arts integration curriculum. In this model, teachers learned art information from the project team that included an Arts Integration Specialist and other highly qualified teachers. Teachers' preparation was sufficient in both studies because they had art models to apply to the STEM curriculum, thus teachers experienced a "systematic approach" of art education.

However, many STEM teachers do not receive enough art education while they are integrating arts into STEM. As Reck and Wald (2018) stated, for those teachers "who do not have formal preparation with arts integration, there exist a great number of challenges surrounding the introduction of arts integration in curriculum" because they often "lack the confidence" (p. 110). Therefore, this study concerns those STEM teachers who need more arts-integration supports and formal art education and explores their stories during arts integration teaching.

Bresler (1995) identified four styles of arts integration in science teaching and learning, they are: a) the Subservient Style; b) the Affective Style; c) the Social Integration Style; and d) the Co-equal, Cognitive Integration Style. With the Subservient Style, arts integration is intended to add interest and motivation to teaching content, which means arts integration plays a subservient role to the teaching content. For instance, in showing students fractions through Leonardo da Vinci's paintings, art plays a subservient role. In the Affective Style, teachers use arts to set the mood for teaching, such as playing sounds of wind to teach content knowledge about hurricanes. In the Social Integration Style, teachers allow students to spend time creating art for community events. In this case, the arts integration curricula cooperate with the school's social function. The Co-equal, Cognitive Integration Style requires teachers with a comprehensive art background or work with art specialists to lead arts integration teaching. For instance, STEM teachers are supported by artists, or they are artists in themselves. These four arts integration styles reflect STEM teachers' various preparations for arts integration.

Bequette and Bequette (2015) and Green and colleagues (2018) believe that arts integration in STEM is a pre-stage of STEAM when a "… focus on synthesizing art, science, and creativity led to the integration of arts into STEM to create STEAM" (p. 15), where "A" stands for arts. Perignat and Katz-Bunonincontro (2018) explain STEAM education is "an acronym for Science, Technology, Engineering, Arts, Mathematics, and used as an interdisciplinary or transdisciplinary approach to teaching and learning that combines the disciplines in a defined learning context" (p. 11).

In STEAM, arts are "combined" with individual or multiple STEM subjects

instead of being "connected" in arts integration. For the combination approach, art is used for teaching other subjects as an inseparable and equal part of STEAM whereas the connection approach refers to arts being used as a tool within STEM contexts. Usually, STEAM schools collaborate with museums, galleries, or invited arts specialists to build STEAM programs or workshops for teachers' preparation (Davis, 2010; Grant & Patterson, 2016; Hunter-Doniger & Sydow, 2016; Plonczak & Zwirn, 2015; Trimble, 2019; Wells & Wagner, 2013; Wylder et al., 2015; Wynn & Harris, 2015). For example, in a STEAM partnership program between an art gallery and a natural history museum, Grant and Patterson (2016) conducted a case study whereby teachers received formal sufficient art education before integrating arts into K-12 STEM lessons. Wells and Wagner (2013) studied a university's Fusion Project that collaborated with a museum to teach mathematics. In this project, math teachers were not required or expected to teach art, and they were not trained in art education. However, they were introduced to the knowledge by museum docents to learn the artistic references, and they were supported by structural suggestions from art consultants. In these two STEAM studies, even though teachers did not have enough art education in preparation for teaching STEAM, they had the gallery or museum as an art supportive path.

In summary, arts-integrated STEM teachers' and STEAM teachers' preparation is different; they are influenced by the curricula structure and state or federal requirements for teachers. However, this study will focus on science and mathematics teachers who do not receive any structured or systematic art education from art workshops, models, programs, galleries, or museums.

The STEAM Education or Arts Integration Implementation

To gain a deep understanding of the impact of STEAM or arts-integrated STEM teachers' preparation in teaching, this section reviews STEAM education and arts integration implementation.

Hunter-Doniger and Sydow (2016) stated that some teachers refused to cooperate with the STEAM or arts integration curriculum because they think these curricula "take too much time to plan, implement, and grade" (p. 164), while some teachers only use arts "as a hook" (p. 163) instead of accessing it through the non-art subjects teaching. Hunter-Doniger and Sydow (2016) found that some other teachers only used arts to "hook" students to begin STEM classes, and then they fell back to the traditional STEM teaching. They did not implement STEAM education or arts integration in its full meaning.

Nonetheless, some schools and projects implemented either STEAM education or arts integration curriculum continuously (Davis, 2010; Grant & Patterson, 2016; Hunter-Doniger & Sydow, 2016; Plonczak & Zwirn, 2015; Trimble, 2019; Wells & Wagner, 2013; Wylder et al., 2015). For instance, Trimble (2019) developed a 15-day residency plan that incorporated weaving arts into a third-grade math curriculum. The teaching artist worked with the school's principal and introduced the concept of weaving and weaving pattern to the entire class. Wynn and Harris (2015) demonstrated a few programs that combine visual arts and K-12 mathematics and science skills. All these STEAM artists and educators who were in these programs had a clear concept for how to combine visual arts with mathematics and science.

Plonczak and Zwirn (2015) set an example for arts integration and STEAM implementation. In collaboration, art and science teachers developed and

implemented lessons together. For instance, they have implemented a combination art-science lesson, which combined Vincent van Gogh's oil painting *Starry Night* with science concepts, such as weather, hurricanes, and global warming. Moreover, they demonstrated cells through drawings that were conducted by art and science teachers. In these lessons, science teachers were teaching students how to observe cells through microscopes, and art teachers were instructing students how to draw cells on paper.

To conclude, the STEAM education or arts integration implementation was successfully complemented each other when mathematics and science teachers were supported by programs or art teachers.

Teachers as Learners

Multiple researchers studied teachers as knowers and learners (Clandinin, & Huber, 2005; Connelly & Clandinin, 1999; Conway, 2001; Fenstermacher, 1994; Florio-Runane, 2000; Korthagen, 2001; Lampert, 1985; 2001; Malcolm et al., 2003; Richardson & Fallon, 2001; Shulman, 1987; Zeichner, 1998). Jurasaite-O'Keefe (2022) explored teachers' learning that expanded their professional knowledge and professional growth at the workplace, and developed a typology of teachers' informal learning as a combination of five aspects: a) dispositions, b) focus, c) reaction, d) sources, and e) process. During their workplace learning, teachers "positioned themselves as informal learners" in different ways (p. 52).

Kyndt et al. (2016) argued that "definitions of informal learning often contrast it with formal learning. Formal learning refers to learning activities that are structured in terms of time, space, goals, and support" (p. 5). By contrast, informal learning happens in unstructured terms of time, space, goal, and support as in visiting a museum to study a painting compared to an art class with an instructor at a museum

site.

Additionally, some researchers discovered that teachers' informal learning changes teachers' conceptions, cognition, or behaviors (Hoekstra et. al., 2009; Jurasaite-Harbison & Rex, 2013; Rehm, & Notten, 2015; Shuell, 1986). In Jones and Dexter's (2014) research, they described how teachers feel independent and free when they experience informal learning. Hoekstra et al. (2009), Rehm, & Notten (2016), and Shapiro (2003) stated that informal learning changes teachers' knowledge and learning and teaching behaviors.

My research employs Jurasaite-O'Keefe's (2022) five aspects of informal learning to identify science and mathematics teachers' art learners' types, and to discover their various informal learning experiences.

Teachers' Professional Identity

Teachers' learning being reflected in their identity. According to Miller (1963), teachers' professional identity means "to be a professional, in general, … a teacher" (p. 89). Since 1970, teachers' professional identities have been separated from the research field of identity as a new research area (Rus et al., 2012). A plethora of research exists on teachers' professional identity development pointing to the factors that impact it (Beijaard et al., 2002, 2004, 2012; Canrinus et al., 2011; Fuller et al., 2013; Pillen et al., 2012; Rus et al, 2013, Timostsuk, & Ugaste 2010; Vahasantanen et al., 2008). Vahasantanen et al. (2008) and Canrinus et al. (2011) posited that the teachers' commitment influences teachers' professional identity. Canrinus et al. (2011) and Fuller et al. (2013) believe that "self-efficacy," "professional efficacy," and "job satisfaction" are important indicators of teachers' professional identity. Kremer and Hofman (1985) and Pillen et al. (2012) studied the relationship among teachers'

professional development, tension, and burn-out, and how these factors interact with each other. Beijaard et al. (2002) and Kremer and Hofman (1985) believe that teachers' professional sub-identities constitutes a part of teachers' identity. Kremer and Hofman further stated that teachers' professional identity encompasses three essential areas: a) a core that contains the defending and coping Ego, b) an intermediate area of multiple social sub-identities, including the "professional" sub-identity in the case of a professional worker, and c) a periphery perceived and labeled by the public, known as the Persona or the Presented Self (p. 90). Beijaard et al. (2002) identified four features of teachers' professional identity: "a) it is an ongoing process of interpretation and re-interpretation of experiences, b) it implies both person and context, c) it consists of sub-identities that are more or less harmonized, and d) agency is an important element of professional identity, meaning that teachers have to be active in the process of professional development" (p. 122).

Beijaard et al. (2004), Timostsuk and Ugaste (2010), and Rus et al. (2013) agreed that teachers' experiences and their professional identity are interwoven. Hence, to study teachers' professional identity, I will be exploring teachers' experiences and stories they tell about their experiences. According to Beijaard et al. (2004), Timostsuk and Ugaste (2010), and Rus et al. (2013), teachers' professional identity contains teachers' self-efficacy/professional efficacy, job satisfaction, professional commitment, teachers' experiences, and professional sub-identity. My study will explore science and mathematics teachers' professional identity development through the lens of Beijaard and colleagues' (2002) four features' framework (which will be explained in detail in the Theoretical and Conceptual Framework section) because they encompass major research results of teachers' professional identities.

STEM Teachers' Professional Identity Development During Arts Integration Processes

This study seeks to understand science and mathematics teachers' transition from STEM to STEAM or becoming Arts-integrated teachers. Therefore, first, I will focus on science and mathematics teachers' professional identity development during arts-integration teaching because when STEM teachers become arts-integrated STEM teachers, their professional identity is likely to change and grow during the arts-integration process. This change will happen due to their professional area shifting from STEM to arts-integrated STEM. Moreover, because teachers' stories are important for understanding teachers' professional identity (Beijaard et al., 2004; Rus et al., 2013), along with the professional experiences, this study explores STEM teachers' backgrounds and stories they tell about their experiences.

Kremer and Hofman (1985) and Beijaard et al. (2002) argued that teachers' professional sub-identity/sub-identities is a significant element of teachers' professional identity. Thus, this research will discuss arts-integrated STEM teachers' professional sub-identity, specifically, teachers' sub-identity that emerges in relation to learning art and pedagogies of art integration. By doing so, I will gain a deeper understanding of arts-integrated STEM/STEAM teachers' professional identity development.

Derived from this literature review, to analyze science and mathematics teachers' professional identity development during arts integration teaching, I developed a new conceptual framework that is based on three previously discussed components (see Figure 1. These three components are: four styles of arts integration in science teaching and learning (Bresler, 1995), four features of teachers' professional identity

development (Beijaard et al., 2002), and five aspects of teachers' informal learning (Jurasaite-O'Keefe, 2022).

CHAPTER 3 THEORETIC AND CONCEPTUAL FRAMEWORK

Introduction

> Arts offers life; it offers the prospect of discovery; it offers light. Resisting, we may make the teaching of the aesthetic experience our pedagogic creed.
>
> (Greene, 1995, p. 133)

To examine and analyze science and mathematics teachers' professional identity development during arts integration, this dissertation argues for the relevance of combining three components and analyzing their interactions as a new conceptual framework. Furthermore, I have built on Vygotsky's social-cultural theory and Greene' theories of the arts and imagination to ground my research from both philosophical and psychological aspects. By embracing theories of Greene (1995) and Vygotsky (1971, 1978, 1995), I illustrate the role of arts in education and the significance of arts integration into mathematics and science curricula. The application of a newly-developed conceptual framework that involves styles of arts integration in science teaching and learning (Bresler, 1995), features of teachers' professional identity development (Beijaard et al., 2002), and teachers' informal learning typology (Jurasaite-O'Keefe, 2022), allowing me to analyze art-integrated teachers' professional identities' growth through three different lenses. In my research, I apply Vygotsky's (1971, 1978, 1995) cultural-historical theory as an umbrella to cover the entire theoretical framework, which includes Greene's (1995) theory of the arts and imagination and other researchers' approaches to Vygotsky's theory. I employ Vygotsky's theory for my theoretical framework in two aspects: the arts in education,

and adults' learning experience.

According to Vygotsky's social-cultural theory, traditional education is retrospective but needs to be prospective, or concerned with the future. Building on Vygotsky, Lindqvist (2010) explained the prospective education "implies that a student should be capable of approaching problems that do not yet exist at the moment. The student must be oriented toward productive (creative), rather than reproductive, knowledge" (Lindqvist, 2010, p. 247), which calls for a creative mind. Arts integration brings creativity into the science and mathematics teaching and learning process, both students and teachers are participating in the prospective education during arts integration. By integrating arts into mathematics and science, both students and teachers are creating instead of reproducing the knowledge.

Art in education is the process of teaching and learning how to create and produce; teachers are the mediators during this productive process, and teaching art relates directly to students' knowledge production (De Souza, et.al., 2021; Khinkanina, 2014; Kozulin, 1993; Lindqvist, 2010; Vygotsky, 1978). Therefore, teaching art stimulates the process of prospective education because of art's creative nature. Vygotsky (1971) posited that one must view art as a special creative component for philosophy and science. Both, Vygotsky's theory and De Souza and his colleagues' (2021) study demonstrate how people bring creativity and imagination to the world when they produce art, emphasizing that both creativity and imagination pervade human existence. Thus, creativity and imagination will be arising when students create or produce art; it will also happen to math and science teachers if art creation or production occur during preparation and teaching process.

Vygotsky (1995) addresses that imagination stems from reality and that "creative

activity is directly dependent upon the individual's experiences" (p. 19). Building on Vygotsky, Lindqvist (2010) notes that "imagination describes a circle. It takes fragments of reality and transforms them and the new fragments take shape and reenter reality" (p. 249). This is why, as Vygotsky (1995) explained, imagination develops creativity—it is both intellectual and emotional. Vygotsky (1971) posits that a kind of "mathematical emotion" will be discovered. He stated that artistic creativity is dominated by emotions. Therefore, integrating art into mathematics and science combines emotional with intellectual activities, which advances individuals' comprehensive knowledge development. Furthermore, arts integration could enhance both teachers' imagination and creativity by building their new mathematics and science teaching and learning experiences. Vice versa, teachers' late learning and teaching experience could impact on teachers' inventiveness.

Greene's (1995) theory further discusses the importance of imagination in developing creativity. She argued that conceiving the arts in education needs both curriculum structure and the awareness of imagination, and one must be "willing to feel and to imagine, to open the window and go in search" (p. 104). She asserted that in "seeking clarity and authenticity in the face of thoughtlessness … we must ask for much the same thing if we truly wish to open the young to the arts, if we are committed to the release of imagination" (p. 126). Thus, according to Greene's theory of the arts in education, the arts and imagination are essential for learning and mutually reinforcing.

According to Vygotsky (1978), the learning process is blended with the development process completely and inseparably. He argued that there is a secret connection between learning a single thing and other unrelated things well, the reason

being that "mental capabilities function independently of the material with which they operate, and that the development of one ability entails the development of others" (p. 82). In other words, learning of one thing stimulates learning of other unrelated things.

When applied to teachers' prefessional growth, learning art can develop teachers' other abilities because learning is "the acquisition of many specialized abilities for thinking about a variety of things" (p. 83). By learning art, teachers can develop the abilities of "observation, attention, memory, thinking, and so forth" (p. 82). Vygotsky (1978) argues that "any improvement in any specific ability results in a general improvement in all abilities" (p. 82).

During the arts integration processes, teachers' professional identity and sub-identity are changing or emerging in the real forms and ideal forms. In real forms, teachers' professional identity can be changed, or new professional identity can emerge by the developing of psychical qualities. In ideal forms, teachers' professional identity can be altered by experiencing art-integrated teaching and learning. Thus, teachers' arts integrated teaching and learning processes are the processes of teachers' professional identity transformation within both real and ideal forms.

Whitehead (2004) defined Vygotsky's social-cultural theory as "the belief that by replacing the acquisition of facts about art with the study of the social elements deemed to be found in works of art, we somehow gain access to deeper meanings" (p. 200). During the processes of arts integration, teachers have an opportunity to comprehend the deeper meaning of implementing art-integrated teaching and learning in STEM education. Teachers' professional identity will be transformed, or new professional identity will emerge when they realize the deeper meaning of the arts

integration.

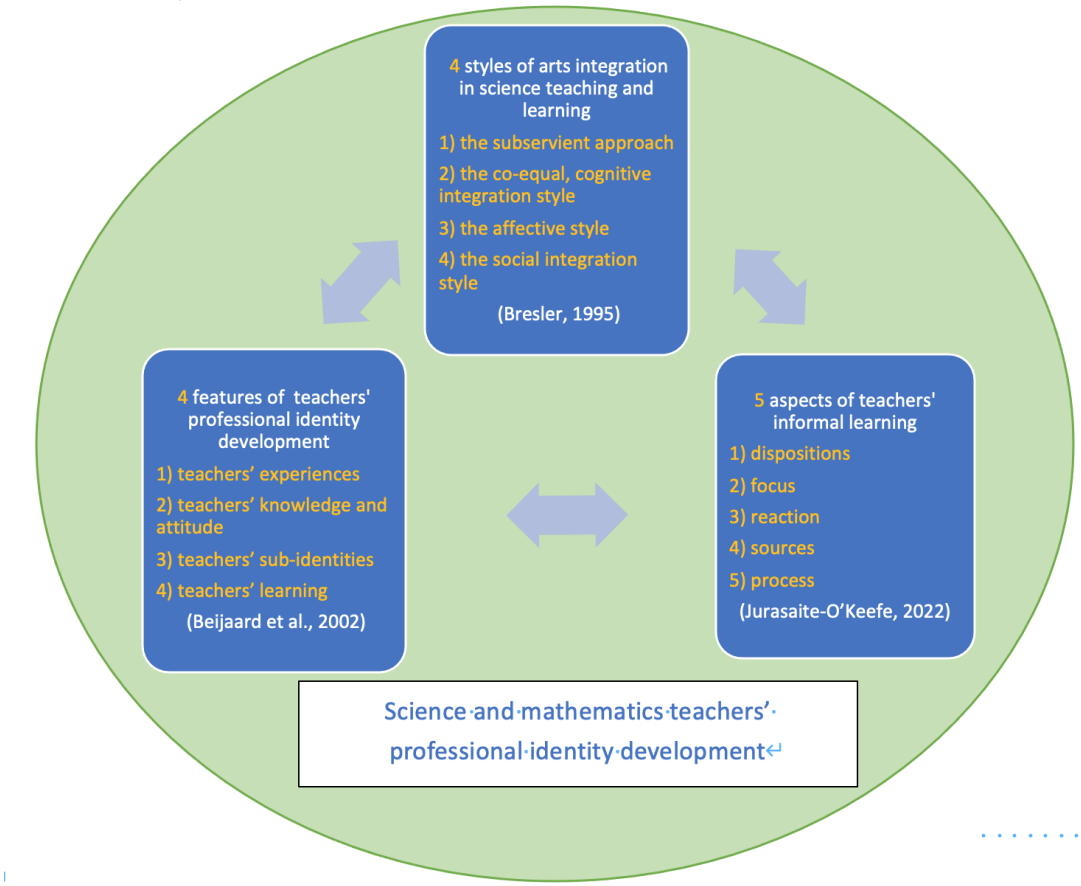
Therefore, my theoretical framework is based on Vygotsky's (1971, 1978, 1995) cultural-historical theory and Greene's (1995) theory of arts and imagination, which allows for a comprehensive examination of arts integration in education, and adults' learning experience related to it. The arts evoke imagination in education, and both the arts and imagination comprise the process of future education.

To study science and mathematics teachers' professional identities through multiple lenses, I employ three frameworks - styles of arts integration in science teaching and learning (Bresler, 1995), features of teachers' professional identity development (Beijaard et al., 2002), and teachers' informal learning types (Jurasaite-O'Keefe, 2022). Discovering the relationship between these three components enables the analysis of the development of science and mathematics teachers' professional identities during arts integration.

Figure 1 demonstrates the conceptual framework of this study, which is explained below, and it includes these three components and the connection between each other. For this dissertation, I use these three components and their relationships to examine the growth of science and mathematics teachers' professional identities through various lenses.

Figure 1

Conceptual Framework of Science and Mathematics Teachers' Professional Identity Development during Arts Integration



Examining Science and Mathematics Teachers' Professional Identity Development through a Lens of Four Arts Integration Styles

According to Bresler (1995), four styles of arts integration in science teaching and learning are the subservient approach, the co-equal, cognitive integration style, the affective style, and the social integration style. Each science or mathematics teacher has their approach to conducting arts integration, and it can be understood as

their style of arts integration. Thus, a science or mathematics teacher's arts integration style can fall under one of these four arts integration styles. During the arts integration, teachers' professional identity changes because it is a dynamic process in which teachers gain new experiences when they learn new art knowledge and arts integration pedagogies. Science and mathematics teachers experience in different arts integration styles experience various arts integration processes. Thus, their professional identities develop under their own arts integration styles.

By examining science and mathematics teachers' arts integration styles, their professional identity development can be explained by their own arts integration styles. For instance, as long as a science or mathematics teacher's arts integration style is defined, it can be used to examine how his/her professional identity changes and grows. Teachers' professional identities are more likely to grow differently under different arts integration styles because teachers' experiences, knowledge, and sub-identities are not the same in various arts integration styles.

Examining Science and Mathematics Teachers' Professional Identity Development through a Lens of Five Teachers' Informal Learning Aspects

As Beijaard et al. (2002) stated, teachers' learning and learning ways constitute a part of four features in teachers' professional identity, which echoes Jurasaite-O'Keefe's (2022) five teachers' informal learning aspects. To understand a science or mathematics teacher's art learning, one must identify how they learn informally by positioning each teacher on the continuum scales of these five aspects. They are dispositions, focus, reaction, sources, and process. Furthermore, a science or mathematics teacher's informal learning type explains his/her art experience, knowledge, and sub-identity related (or not) to art.

While science and mathematics teachers implement arts integration, they need to learn art informally if they have not received formal art education. Even though some of them attended a short-time art workshop or program, the art knowledge they have learned might still not be enough. Hence, they will need to continue art learning informally. Because their roles include both arts-integrated science and math teachers and art learners, science and mathematics teachers' professional identity is likely to develop during their informal learning and their roles' transition. At the same time, their informal learning types represent their ways of gaining experiences in which they attain knowledge and develop their sub-identities.

Examining Science and Mathematics Teachers' Professional Identity Development through a Lens of Interactions Among Three Frameworks

In this newly created conceptual framework, the three frameworks are structured to explore science and mathematics teachers' professional identity development. To reveal an underlying connection between these three frameworks and science and mathematics teachers' professional identity development, it is important to identify the role each part plays in this conceptual framework. These three frameworks show teachers' professional identity development, teachers' arts integration styles, and teachers' informal learning.

For example, when analyzing the interaction between science and mathematics teachers' arts integration styles (Bresler, 1995) and teachers' informal learning types (Jurasaite-O'Keefe, 2022) I will be able to see if teachers' informal learning types influence teachers' arts integration styles or it works the other way defining if different arts integration styles require different art preparation and learning or different preparation and learning define a specific arts integration style. Moreover,

these two frameworks and the interaction between them relate to teachers' four features in professional identity (Beijaard et al., 2002) because science and mathematics teachers' professional identities emerge and develop during their various learning experiences and arts integration processes. Therefore, all these three frameworks and the relationships among them allow to examine teachers' professional identity development in a comprehensive way.

CHAPTER 4 METHDOLOGY

In this chapter, I first remind my research questions because they guide my research methodology and the study design. Then, I demonstrate my research design by presenting an introduction of the case study, the benefits of the case study, the researcher's positionality, the research sample, data collection and analysis, and the limitations and tensions of the study.

Research Questions

To examine arts-integrated science and mathematics teachers' professional identities development during arts-integrated teaching, this dissertation explores:

1. Why do (certain) science and mathematics teachers integrate arts into their teaching?
    a. How do science and mathematics teachers' personal experiences and background influence their arts-integration teaching (if at all)?
    b. What do science and mathematics teachers think an arts-integrated science and mathematics teacher should know and teach?

To examine arts-integrated science and mathematics teachers' sub-identities in professional identity development, this study explores:

2. What are arts-integrated science and mathematics teachers' sub-identities?
    a. What is the relationship between their sub-identities and learning arts?
    b. How do their sub-identities interact with their professional identities?

Research Methodology

Research Design

The multiple-case study design involves an in-depth examination, detailed

definition, and interpretation (McMillan and Schumacher, 2006) of two cases. The cases are "anchored in real-life situations [the analysis of which] will result in a rich and holistic account of a phenomenon" (Merriam,1990, p.32).

Because my study is based on three science and mathematics teachers' real-life teaching and learning experiences, this design allows me to examine and understand teachers' professional identity development during arts integration.

Introduction of Case Study

In this section, I provide case study background information, and show case study's basic styles created by Yin (2014). Furthermore, I explain case study's benefits and limitations, as well as my research sample, data collection and analysis, and the researcher's positionality.

According to Merriam (1990), "a case study is an examination of a specific phenomenon such as a program, an event, a person, a process, an institution, or a social group" (p. 9).

Yin (2014) defined a "case" as "generally a bounded entity (a person, organization, behavioral condition, event, or other social phenomenon), but the boundary between the case and its contextual conditions–in both spatial and temporal dimensions—may be blurred, as previously noted" (p. 25).

Merriam (1990) stated that "the bounded system, or case, might be selected because it is an instance of some concerns, issue, or hypothesis" (p. 10).

The researcher needs to select their case under "some compelling theoretical framework" to make the case study "special" and "contribute to the research literature" (p. 25).

There are various methods for collecting case study data, such as direct

observations, participant observations, audiovisual material, interviews, documents, reports, and physical artifacts (Creswell and Poth, 2018; Merriam, 1990; Stake 1995; Yin, 2014).

Merriam (1990) identified three types of case studies in education that are influenced by sociology, history, anthropology, and psychology. They are an ethnographic case study, a psychological case study, and a sociological case study. Case studies can be classified "by the nature of the final report" (Merriam, 1990, p. 27). They are descriptive case studies, interpretive case studies, and evaluative case studies. A descriptive case study refers to "a historical case study that chronicles a sequence of events" (p. 27).

Interpretive case studies "are used to develop conceptual categories or to illustrate, support, or challenge theoretical assumptions held prior to the data gathering" (p. 28). "Evaluative case studies involve description, explanation, and judgement" (p. 28). Thus, case studies can be categorized by "their disciplinary orientation, by the end product, or by some combination of two" (p. 29).

Yin (2014) distinguished four types of case study designs that are based on single and multiple case studies represented in Figure 2:

Figure 2

Robert.K. Yin's Basic Types of Designs for Case Studies

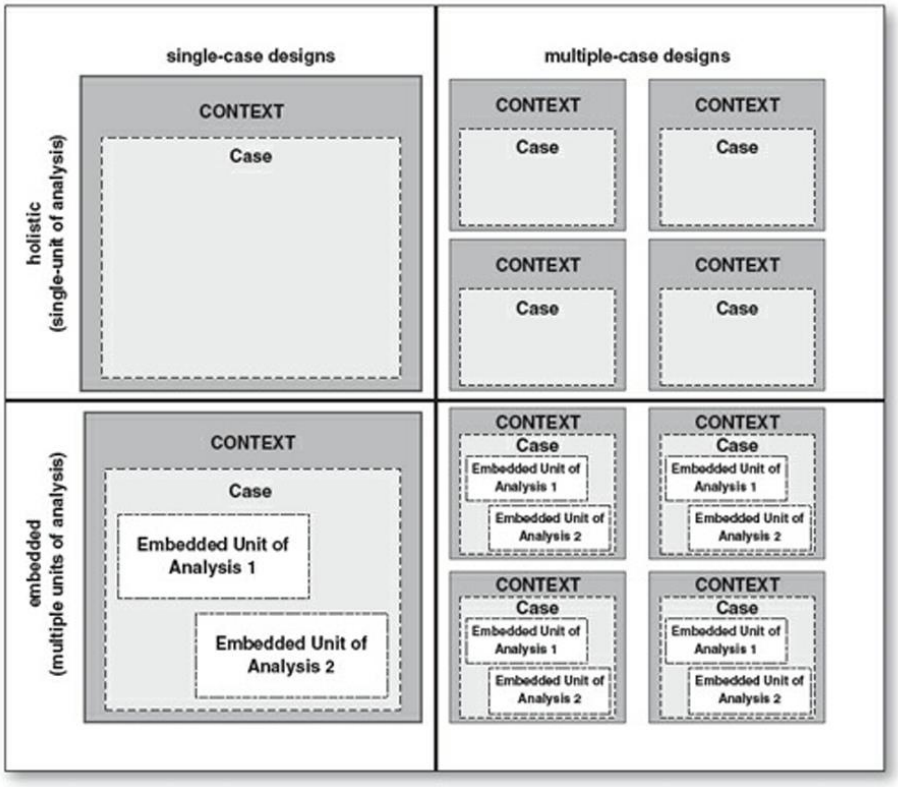


Figure 2 illustrates four types of single or multiple-case studies design. The holistic level refers to the analysis of data in a single unit, the embedded level means the data is collected and analyzed from multiple sources. Yin (2014) explain that the implementation of the multiple-case design is more difficult that the single-case design, however, the multiple-case design will provide greater confidence to research findings. The case study would not have "a tallying of the cases … [but would] provide a useful way for deciding whether the group of cases … supported an initial proposition…" (p. 26). In other words, the number of participants in the case study does not impact the research result.

Creswell and Poth (2018) posit that "the case study approach is familiar to social

scientists because of its popularity in psychology (Freud), medicine (case analysis of a problem), law (case law), and political science (case reports)" (p. 97). Stake (1995) established systematical case studies' research procedures, and Stake (2006) presented the structured case study approach.

As Tellis (1997) mentioned, the case study has been used as a form of research that can be traced back to France in Europe. "From the early 1900's until 1935, The Chicago School was preeminent in the field and the source of a great deal of the literature" (p. 3). The case study has been established as an appropriate research method for the research project by Levy (1988) at Fairfield University. Merriam (1990) and Yin (2012) have developed and introduced the case study research in education, and I apply Merriam (1990) and Yin (2012)'s case study approach as my research methodology references.

Benefits

According to Merriam (1990), the strengths of case studies include "the predictive nature of the research findings" and "the best plan for answering one's questions" (p. 32).

Furthermore, the case study is based on "real-life situations", thus it "offers insights and illuminates meanings that expand its readers' experiences. These insights can be construed as tentative hypotheses that help structure future research" (p. 32). Case studies are ideal for applying in the field of knowledge because of those advantages, therefore, the case study is "a particularly appealing design for… education" (p. 32).

Sample

At present, there are four art-related out of 16 main learning programs in New York City Department of Education (DOE), they are NYC GREAT!, NYC Community

Schools, Inclusive Student Opportunities and Resources, and IMAGINE NYC Schools. NYC GREAT! provides the opportunity to visit CNN studios and join the Tribeca Film Festival to help students explore their career interests. NYC Community Schools offers arts and music lessons during the summertime after school. The inclusive Student Opportunities and Resources program encourages students to participate in the annual Disability Pride Visual Arts Contest by submitting their visual artwork. Particularly worth mentioning is the program of IMAGINE NYC Schools, the goal of the program is to reimagine existing schools and design new school models. The program calls up teachers, professionals, designers, and artists to join the design team to build innovative school models.

Furthermore, DOE is holding eight arts education programs currently, and three of them are linked with visual arts. They are P.S. Art, Ezra Jack Keats, and ArtsSPACE (Supporting Performing Arts and Creative Education) Grants. Up to 25 Pre-K-12 schools or campus sites were awarded by the ArtsSPACE Grants to establish or reburnish these schools' visual arts space. There are ten arts festivals in 2022, and 37 arts and education organizations in DOE in total.

Cruzes et.al. (2015) argue that cross-case analysis is a method that facilitates the comparison of commonalities and differences in the event, activities, and processes. I examine commonalities and differences by comparing two participants. The participants of my study are high school mathematics and biology teachers who were bringing visual arts to their teaching process.

Both of the participants are female high school teachers, and the highest degrees of them are Master's. They are from a private Catholic high school in New York City, one of them is a biology teacher and the other is a mathematics teacher. Currently, the

high school is a STEAM school and the STEAM program have been introduced here since 2019.

There are two reasons to select this school as my research cite. Firstly, my research studies teachers who are implementing STEAM education and arts integration. In comparison to traditional schools, the STEAM school is a better place for researching art-integrated STEAM teachers' teaching and learning. Secondly, even though both of teachers are from the same school, they are different individuals. By knowing and comparing these two teachers' arts integration processes, I will be able to view both teachers' professional identity growth trajectory under the same circumstances.

The biology teacher is the lead teacher of the grade, and she is an art enthusiast for both performing arts and visual arts. Conventionally, her school was not implementing STEAM or arts integration, however, she was the first teacher to bring arts to the biology teaching, attempting to promote arts integration in the school. Sequentially, other teachers started to be interested in integrating art into their science or mathematics teaching, and the school changed its direction from indifference to supporting arts integration and STEAM. In 2022, under the common efforts of the biology teacher and other science/mathematics teachers, their school held a cooperating program with the National Aeronautics and Space Administration (NASA). Currently, the school is a STEAM school. The other participant is a mathematics teacher from the same high school. She was trying to implement art integration in her class and let students make artwork by applying mathematics.

Data Collection and Analysis

According to Yin (2012), there are six common sources of evidence in doing the case study: (a) direct observations; (b) interviews; (c) archival records; (d) document;

(e) participant-observation; and (f) physical artifacts. (p. 27)

I started my data collection in the middle of the semester. I implemented interviews, observations, and physical artifacts to analyze both science and mathematics teachers' art-integrated teaching and informal learning. I observed each participant more than twice and I took the observation notes during observations, and these notes were coded together with other data.

I interviewed participants 2-3 times, the first interview focused on their past arts integration experiences, and it was started in the middle of the semester. For the second or third interviews, I asked about their experiences or future plans for arts integration which was conducted at the end of the semester. By doing so, I collected the data from different times or stages of teachers' arts integration implementation, and analyzed it to understand the arts integration process along with changes in teachers' thinking during the semester. Along with interviews, I had a personal talk with the biology teacher to learn more about her thoughts on arts integration.

Moreover, I collected physical artifacts, which included the teacher's PowerPoint, handouts, math games, watercolor painting, artwork, and students' artwork. Further, I analyzed these physical artifacts as examples of arts integration. All these data were coded by hand and NVivo, which was divided into a few main themes under my newly-developed conceptual framework (see Figure 1), and the next step was to analyze the data under these themes.

For the observation part, my first observation was a STEAM lesson which was taught by both the art teacher and math teacher together, the activity of the class was using watercolor painting to combine with algebra questions. I chatted with both teachers before the class began, and I gained basic information of the class and teachers'

thoughts on this STEAM lesson. My second observation was the biology class, and the teaching content was “Female Reproduction Study”.

My third observation was mathematics class, particularly in algebra. Before the observation, the math teacher told me that there would probably be no arts integration in her class for the rest of the semester, and she explained that she has done several art-integrated classes this semester, including the STEAM club lesson I observed earlier. Therefore, I told the math teacher that I would still go to the math class to observe, and that she does not need to add art if she does not want to. However, she has conducted a game play in this class. The game was asking students to throw a bottle in groups, and then to record how many times the bottle can be straight up, the math teacher told me that this purpose of this game is to help students understand the content of “probability” in mathematics. Furthermore, I have implemented my first interview with her after this class, and I asked more questions than I have planned after the observation. Therefore, I decided to proceed my second interview with math teacher after observing her next class.

My fourth observation was a DNA lesson from the biology class, the biology teacher told me that this content is from college textbooks, however, she wanted to try to teach it in high school by integrating arts. At the beginning of the class, the biology teacher was bending a “Formstruction Set” and stabbed plenty of color pins to show students the folding protein and key in DNA. During the class, I was both an outsider and an insider in this observation, besides observing class and taking notes, I was walking around the classroom to look at students’ work and take photos for STEAM department use. The fifth observation was mathematics class, the math teacher asked students to play a math board game in the class instead of arts activities. I took the

second interview with Zoe after this class's observation, and I asked two more questions popped up during the observation.

Among these observations, I took notes when I was observing class, and I focused on teachers' teaching rather than students' performance. What is more, I wrote a memo after every observation and interview. By doing this way, I could immediately record my thoughts and questions, so that I can explore further after every observation and interview for my research. I was a complete outsider in mathematics classes' observations because I was only observing and taking notes. However, I was both an outsider and an insider in biology classes' observations. The reason behind this is that I knew the biology teacher and students from the biology class better since she introduced me to all the students in the first class. Moreover, I joined the STEAM department's field trip with students, the biology teacher, and the art teacher after my first observation. Thus, sometimes I chatted with the biology teacher and students before the class, as well as assisted with her in the class. Another reason is that she is my friend and my classmate in the same Ph.D. program, I intended to be more involved in biology class and learn more about biology teaching. I believe these are reasons for I could not stay entirely an outsider for observing biology class.

During my research, there was a special experience for my observation: the STEAM club field trip. The STEAM club is a group established by the STEAM department, which includes art and science groups of students from various grades. STEAM club field trip is a one-day trip at a park in Upstate New York for both science students and art students, the biology teacher and art teacher organized art and science activities at the park for students. The biology teacher told me that it is the third year they have held the field trip, and the purpose of this trip is to help students

see and understand science and arts in nature. I joined this trip as a complete insider.

My last observation was to observe the art teacher and math teacher collaborate with each other in preparing STEAM lessons. Usually, the math teacher works with the art teachers to discuss and share ideas of arts integration for preparing future STEAM classes, thus I went to observe one of their preparations to see how the mathematics and art teachers cooperate with each other. I was completely an outsider during this observation, I was taking observation notes without a word. At first, the math teacher showed an image from a website told the art teacher her thoughts about it and asked his opinions of the art-integrated math lesson from the website, the art teacher immediately gave two options to improve and implement the lesson. In the whole process of the mathematics and art teacher's collaboration, the math teacher demonstrated her ideas by using examples online, and asked the art teacher if it was "doable" and how to make the activities apply to their class. The art teacher answered the math teacher's questions all the time and gave his suggestions. Moreover, the art teacher explained the basic art knowledge to the math teacher during the preparation, such as how different art mediums work in various ways: watercolor and colored pencil, and art concepts, for example, color theory and paper sculptures.

Situating the Researcher

My experience includes multiple roles that prepared me to conduct this study with a deep understanding of arts and arts integration into a mathematics curriculum. I was a lead teacher of an after-school mathematics program in a K-12 school in New York City from July 2018 to July 2021. In the mathematics program, the program's mission includes helping students and their parents to build mathematical confidence and competence through solving problems. There are no exams or any other means of

testing in this program. Instead, the emphasis is on participating in various math-related activities, such as designing mazes, creating songs, cooking, and so on. During the teaching, I discovered that students are motivated to participate in conducting mathematics when they are involved in math-related activities, including visual arts-integrated math activities. When I was teaching and conducting the activities with students in the program, my researcher's positionality was of an insider - a mathematics teacher.

In the meantime, I am an artist, and I joined an artists' meeting group named "Artists of the Met" in June 2021. The artists' group is founded and organized by an undergraduate student from Cooper Union; up to fifteen artists meet every weekend to draw or paint together in the museum or park. This group aims to connect with artists and to share with artists creative ideas and skills. In the artists' group, I am experienced in creating art, hence, my researcher's positionality is of an insider - an artist as well.

In my research, my researcher's positionality moves from a mathematics teacher to an artist. I see art-integrated teachers' teaching and informal learning experience through the lens of a mathematics teacher and an artist.

In my view, visual arts is a form of direct explanation of some mathematics problems. Students can be attracted by visual arts and willing to learn more about it. For some students who think mathematics is "hard" and "difficult", visual arts can be a good tool that serves as a motivation for students' mathematics learning. As an artist, I thought I do not need any additional learning to learn visual arts for my mathematics teaching. However, drawing with the artists' group inspired me more to integrate arts into mathematics, and I enjoy bringing art to the class. As a visual artist, I am learning how to create art. As a mathematics teacher, I am learning how to integrate visual art

into math teaching.

Limitations and Tensions

Merriam (1990) concluded limitations of case study, they are the length and details of research for policymakers and educators; readers might see case studies as a whole instead of a part of life; both readers' and researchers' biases can impact the research result. Moreover, there are debates connected with case studies' generalizability, such as "some assume that one cannot generalize from a case study and count as a limitation of the method", however, some others "argue that rather than applying statistical notions of generalizability to case studies, one should develop an understanding of generalization that is congruent with the basic philosophy of qualitative inquiry" (p. 35).

To conclude, case study is a research approach that is derived from social science research. When the researcher is conducting the case study in education, they can benefit from the structured research process to answer research questions. There are tensions to conducting a case study approach, however, Merriam (1990) stated that the case study's strengths outrank its limitations. For my case study, I agree that my biases could impact the research result. Readers might see this case study as participants' entire arts integration experience rather than a part of participants' arts-integrated teaching and learning experience.

CHAPTER 5 FINDINGS

In this chapter, I am analyzing the data, which includes three teachers' interviews, observation notes, and physical artifacts. To explore arts-integrated science and mathematics teachers' professional identities' development during arts-integrated teaching, I am discussing the following questions: How do (certain) science and mathematics teachers integrate arts into their teaching? How do science and mathematics teachers' personal experiences and background influence their arts-integration teaching (if at all)? What do science and mathematics teachers think an arts-integrated science and mathematics teacher should know and teach? What is the relationship between their sub-identities and arts? How do their sub-identities interact with their professional identities?

My findings include the analysis of mathematics and biology teachers' arts integration styles. In addition, I will employ three parts of my framework, which are four styles of art integration in science teaching and learning, four features of teachers' professional identity development, and five aspects of teacher's informal learning and how they apply to each teacher (see Figure 1 in chapter three) to find answers to the questions listed in the previous paragraph. This framework will help me to identify their arts integration styles and how they are related to their professional identity's and sub-identity's development.

I present my findings in the following way: I analyze each of the two participating teacher's experiences and their reflections on their experiences separately, first describing their background and then applying four styles of arts integration in science teaching and learning framework to find out each of the teacher's arts integration style. Then, I apply four features of teachers' professional

identity development framework to examine the mathematics teacher's professional identity structure. Further, I will examine the biology teacher's professional identity structure. Lastly, I employ five aspects teachers' informal learning to analyze teachers' dispositions, focus, reaction, sources, and process during their arts informal learning.

I will start my analysis by introducing the art teacher, who plays a major role as the main resource for their learning in the participating teachers' development.

Art Teacher Charles

Charles' Background

Charles is a male high school art teacher. He has been a member of the STEAM department for the last five years, and he is the only art teacher providing professional advice to other teachers in the STEAM department. Charles plays the role of an art specialist in all art-integrated STEAM classes and projects of the school, and he is responsible for assisting the biology teacher and other teachers with arts integration preparation and implementation. Charles enjoys using art as a tool to help students learn in other fields, and he believes that students do not need to be good at art to practice art. In this chapter, I will use my interview with Charles to support my findings.

Mathematics Teacher Zoe

Zoe's Background

Zoe is a female high school mathematics teacher. Zoe only teaches algebra and has taught algebra for five years. She joined the STEAM department of the school when she graduated from graduate school. STEAM department is divided in groups, and the group Zoe belongs to is the one that has the biology teacher Erin and the art teacher Charles. Zoe loves mathematics and liberal arts. Along with a master's degree in

mathematics education, Zoe holds a master's degree in English literature. Zoe is a young teacher who takes delight in guiding students to learn mathematics through various ways such as watercolor painting, mathematics games, three-dimensional paper sculptures, and stained glass creating.

Zoe's Arts Integration Styles

In this section, I will identify the mathematics teacher Zoe's arts integration teaching and learning styles. Moreover, I will examine Zoe's professional identity structure through the lens of arts integration styles' framework.

According to Bresler's definition (1995), there are four styles of arts integration in science teaching and learning. Zoe's arts integration seems to span between two styles: the co-equal, cognitive integration style, and the social integration style. The co-equal, cognitive integration style requires teachers to have a comprehensive art background or work with art specialists to lead arts integration teaching (Bresler, 1995). Zoe seems to collaborate with the art teacher Charles, who works in the same STEAM department. As I observed a STEAM department meeting, Zoe and Charles were discussing the teaching plan for the coming week and reflecting on their arts integration teaching in the past week. In addition, I observed Zoe and Charles's meeting on June 12, 2023, which demonstrated how they collaborated to design next semester's art-integrated mathematics class and STEAM lessons. During the meeting, Zoe showed Charles many examples and pictures of art-integrated math projects and asked for his suggestions about how to apply and improve those projects in teaching her class and in co-teaching STEAM lessons. For example, Zoe asked Charles about an architecture game project she has found online, and she wondered if the students would be capable of implementing it. Charles explained the art and skills needed to implement it. He

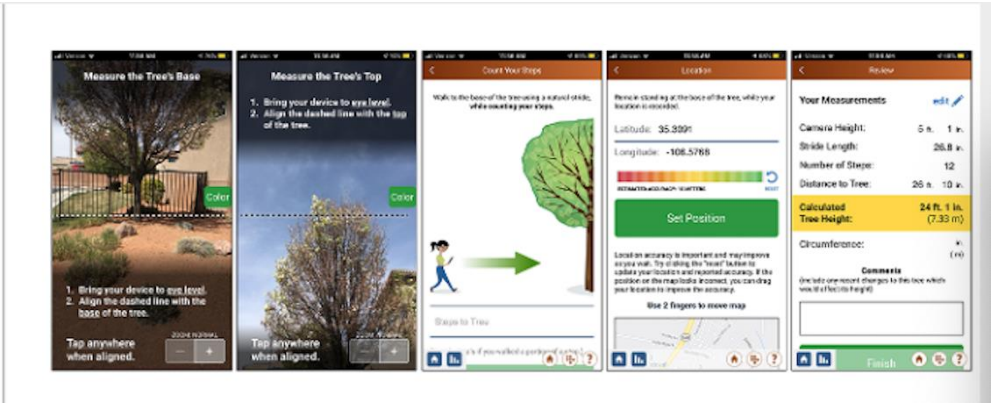
suggested Zoe to simplify the design of the architecture part so that she could lead students to practice this project.

Zoe cooperates with Charles throughout the whole process of arts integration teaching and learning. As Zoe said in the interview on May 11, 2023, "I teach math, our art teacher, science teacher, our music teacher, we're all sitting together, […]as we're talking about different activities or different lessons, whatever material we're covering in". Their discussion included what they have done in the past weeks for art-integrated teaching and sharing the teaching plans with others. When Zoe talked about her art learning experience, she said one of her methods is "talking to our art teacher" and "going to check with our art teacher to make sure that I'm explaining it correctly" (Interview on May 11, 2023). Thus, by working with the arts teacher, Zoe implemented her art-integrated teaching by receiving the art teacher's support. Therefore, one of Zoe's arts integration styles seems to reflect the co-equal, cognitive integration style, which is defined as working with art specialists (Bresler, 1995).

In addition to using the co-equal, cognitive integration style, Zoe applied the social integration style. Zoe guided students in participating in community events by conducting arts-related activities. Zoe shared a story that happened in October 2021, when the biology teacher Erin and Zoe organized students to measure the trees' length, circumference, and diameter to see the trees' growth and take photos in front of the school, National Aeronautics and Space Administration (NASA) noticed this project on the school website and contacted Zoe to provide the data for NASA. Furthermore, NASA scientists published an article that included the data the teachers have uploaded to NASA. Figure 3 demonstrates Zoe and students' data on trees in the NASA scientists' article.

Figure 3

Zoe and Students' Data on Trees in the NASA Scientists' Article



As Bresler (1995) stated, under the social integration style, teachers guide students to spend time creating art for community events. Zoe and the students spent eight school days measuring and taking pictures of trees, and NASA posted a video of Zoe and the students introducing their project on NASA's social media platform (Instagram) named NASA Climate Change, so that more people in the community would be able to access this information. Therefore, during integrating arts in her mathematics teaching Zoe also applies the social integration style defined as leading students to conduct art activities to participate in community events (Bresler, 1995).

Examining Zoe's Professional Identity Structure

I am applying the framework of teachers' professional identity (Beijaard et al., 2002) in relation to two arts integration styles that she exhibited which are the co-equal, cognitive integration style and the social integration style. Each paragraph will contain the analysis of one of the four features of the framework, which are: "a) it is an ongoing process of interpretation and re-interpretation of experiences, b) it implies both person and context, c) it consists of sub-identities that are more or less harmonized and d) agency is an important element of professional identity, meaning

that teachers have to be active in the process of professional development" (p. 122).

Firstly, I examine how Zoe's experiences of arts integration relate to the structure of her professional identity under the co-equal, cognitive integration style. According to Zoe's art integration teaching experience, she believed that the middle of the semester is the best time to implement art-integrated mathematics projects and classes. The reason behind this is "the beginning of the semester is more of an introduction, so it's like solving basic equations…the end of the semester probably depends", and "the middle of the semester is the easiest part just because students have the foundation that they need, so we can go back, to bring in easier topics ," said Zoe on May 11, 2023, in the first interview. Zoe gave an example from the STEAM lesson that I observed, which connected to watercolor proportion and ratio learning, and it was carried in the middle of the semester. Figure 4 illustrates the art teacher's visual explanation of proportion and ratios by applying the watercolor mixtures. Zoe worked on implementing art-integrated mathematics classes in different time periods. To capture the process of her learning to integrate arts, Zoe has created a timeline for her arts-integration teaching.

Figure 4

Watercolor Proportion and Ratios Lesson

Further, I examine how Zoe's knowledge and attitude are related to her professional identity structure. Zoe expressed that she "really love[s] math" and she knows that "most people don't like math". However, she hopes "to make it more relatable and easier for a kid to understand as they're going through the material", said Zoe at the beginning of her first interview on May 11, 2023. As a mathematics teacher who wants to make mathematics "more relatable and easier" to understand, Zoe believes that arts keep students engaged or "somewhat engaged", and art is "partially a motivator" for "the kids who really excel in art and don't excel in math, or just have that interest in the creativity aspect" in mathematics learning (Interview on May 11, 2023). Zoe's knowledge of mathematics made her become a high school mathematics teacher, and Zoe's attitude toward arts integration is applying arts as a partial motivator to teach mathematics, both of which play an important role in her becoming an art-integrated mathematics teacher who finds a way to understand how students "learn best" and who helps students "make sense" of mathematics (Interview

on May 11, 2023). Zoe is working to assist students in learning mathematics by integrating arts into her classes.

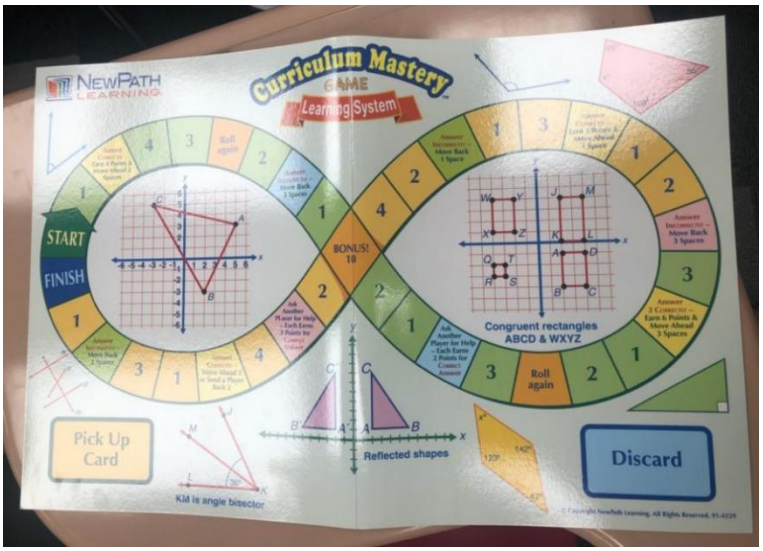
Moreover, I examine Zoe's sub-identities during her professional identity development. As a member of the STEAM department, Zoe has been an art-integrated mathematics / STEAM teacher for five years since she started teaching in this school. Zoe admitted she loved arts despite being "not great at it". If she wants to bring arts into her class by herself, she would "look up kind of the basic level of art" (Interview on May 11, 2023). Interestingly, two classes that I have observed for Zoe were not art-integrated, but game-involved mathematics classes. As Zoe explained, playing a game in class is more feasible because sometimes students are overthinking the art portion, or they are overthinking the mathematics portion which takes more lesson time when they see arts integration as two separate classes.

Zoe's views above lead to discern that Zoe has two professional sub-identities. These two sub-identities are: a mathematics teacher who is not good at arts, and a math-related games lover and practitioner. These two professional sub-identities impacted Zoe's arts integration teaching; she was not very confident in integrating arts into mathematics class when she was preparing a class alone. Hence, games replaced art in Zoe's mathematics class as "a second step for art" (Interview on May 11, 2023). Figure 5 shows one of the math-related games Zoe applied in the class, an infinite symbol-shaped board game, challenging students to apply the theoretical concepts described during the class.

Therefore, the data showed that Zoe's professional identity of a mathematics teacher who wants to help students and her sub-professional identity of a mathematics teacher who is not good at arts led Zoe to become a math games fancier practitioner.

Figure 5

One of the Math Games



Last, I examine Zoe's learning during the professional identity development. The art teacher Charles described Zoe as a "very forward-thinking teacher" (Interview on May 25, 2023); Zoe always talks to him to see if there are any art-math activities they can implement together. During the observation on June 12, 2023, at Zoe and Charles's meeting, I noticed that Zoe introduced many online arts integration mathematics projects, and asked Charles's opinion to make those projects feasible for the mathematics class.

As Zoe portrayed herself, she "would look online" to learn art-integrated mathematics projects in advance, and she "would talk to the art teacher". Moreover, Zoe would "either seek out another math teacher or speak to the coordinator or whoever would be the most helpful in the situation" (Interview on May 11, 2023). Zoe mentioned that she would talk with the art teacher and other mathematics teachers at the STEAM department meeting. Zoe shared, "We're all sitting together, and as we're talking about different activities or different lessons, whatever material

we're covering, sometimes that discussion just sparks an idea" (Interview on May 11, 2023). Along with these ways of learning, the STEAM department has a Google Drive link to share each teacher's ideas, and teachers can upload their class designs online. The same as other teachers, Zoe can access these materials and learn from them. To conclude, as Zoe explored various ways to learn how to be an art-integrated mathematics teacher, she learned from online sources, the art teacher, and other mathematics teachers.

In summary, Zoe's professional identity development through a lens of the co-equal, cognitive integration style demonstrates that Zoe encompasses her arts integration experience, knowledge and attitude, learning, and sub-identities of a mathematics teacher who is not good at arts, and a math-related games lover and practitioner.

Secondly, I will examine mathematics teacher Zoe's four features of professional identity through a lens of the social integration style. First, I will discuss Zoe's experiences that comprise her professional identity in the social integration style. By cooperating with NASA, Zoe gained the experience of communicating with NASA scientists via emails and virtual meetings to discuss the project's plan and steps. Simultaneously, Zoe became a bridge between NASA and students to ask and answer students' questions for this project. In the end, Zoe collaborated with co-authors on a research article. Moreover, Zoe and students created a video reel on an official NASA's social media platform.

Further, I will examine how Zoe's knowledge and attitude reflect on her professional identity. Zoe used her knowledge of mathematics to implement the project, using techniques such as asking students to measure the circumference of

trees instead of only the height, so that students could understand that trees are not only growing in height but in circumference too. Additionally, Zoe showed her attitude of discretion to this program, as she said, "I wanted to make sure I didn't mess anything up" (Interview on May 22, 2023). This quote indicates that Zoe implemented this project with care and respect.

In addition, I examine Zoe's learning during her professional identity growth. Zoe explained that "what [she] learned more about was the science aspect", and she had not "used it to incorporate art yet" (Interview on May 22, 2023). Furthermore, Zoe learned how to use the NASA's application to upload the data to NASA. She also learned the procedure of writing a science article and collaborating on it. Hence, Zoe's learning is neither in art nor in mathematics area. Learning happens through social interaction, such as communicating with NASA scientists to learn how to choose the data for the article and creating a video reel with students on a NASA's social media platform.

In conclusion, according to the data that I have collected, Zoe did not reveal any sub-identity during her professional identity development under the social style. An interesting finding is that Zoe expressed that she "love[s] art" (Interview on May 22, 2023). However, Zoe did not mention going to museums or galleries in person or online during her leisure time to learn more about arts. The data shows that perhaps Zoe is not an art admirer, but an art practitioner due to her professional identity—an art-integrated mathematics teacher.

Zoe's Informal Learning of Arts

In this section, I will analyze Zoe's informal learning of arts using Jurasaite-O'Keefe's (2022) framework that includes five teachers' informal learning aspects.

These are dispositions, sources, reaction, focus, and process.

Zoe's Dispositions

Jurasaite-O'Keefe (2022) identified three types of dispositions to describe informal learners, which mark two most extreme and a middle point on the continuum. They are opportunistic learners, opportunistic/proactive learner, and proactive learners. As Jurasaite-O'Keefe's (2022) argued that when describing their learning experiences, opportunistic learners "tended to provide a simple structure: they described a learning situation, expressed their emotional attitude, and concluded with a general closure" (p. 58). On the contrary, proactive learners "demonstrated a highly proactive mode of disposition to informal learning" (p. 65). In other words, proactive learners tended to evaluate what they needed to learn and plan for learning. Opportunistic/proactive learners demonstrate a combination of both features of opportunistic and proactive learners, and they usually take "opportunistic stances in some situations and proactive in others, yet they still actively took part in different learning practices" (p.65).

When Zoe described how she prepared art-integrated class or co-prepared STEAM lesson with the art teacher, she said that she found most of the resources online or from discussions with the art teacher, as she said, "I'm pretty much either talking to our art teacher, looking online, or talking to someone else who's done something similar" (Interview on May 11, 2023). Furthermore, Zoe practiced her new understanding of arts within her teaching. As she explained her learning experience of arts, "you need to have enough of an understanding that you could explain it. Whereas learning it [arts], you might think you understand it and you don't realize if you're confused until you have to explain to someone else" (Interview on May 11, 2023).

Zoe added, "learning arts, you might hear things and absorb some of it, whereas teaching it, you have to have such a knowledge and understanding of that you can explain enough of it so that they [students] will understand" (Interview on May 11, 2023). In addition, the art teacher Charles depicted Zoe as "a very forward-thinking teacher" (Interview on May 25, 2023). These data demonstrated that Zoe is an art-integrated mathematics teacher who likes to learn arts in an active way and teach students with her new comprehension of art. Therefore, Zoe is likely a proactive learner during her informal learning of arts.

However, Zoe mentioned that when she was a student teacher, she "didn't really [do] much art", and the arts Zoe learned before she became a STEAM teacher was "just in school, different classes, different electives, from high school to college" (Interview on May 11, 2023). These data showed that Zoe was not a proactive learner before she became a STEAM teacher, and her art learning was simple and passive. Thus, the data demonstrated that Zoe's disposition of informal learning of arts changed from that of an opportunistic to that of a proactive learner during these five years of her STEAM teaching period.

Zoe's Source of Learning

Jurasaite-O'Keefe (2022) categorized three types of informal learners based on their sources of learning, which include two extreme points and the combination of both as a middle point on the continuum. They are individual learners, individual/social learners, and social learners. The individual learners focus on learning from the sources they find individually, and they tend to "reflect on their personal or professional problems and [deal] with dilemmas on their own" (p.71). Social learners, on the contrary, communicate with various people who would give

them feedback and offer different resources. Individual/social learners use both social and individual sources of learning.

During the interview on May 11, 2023, Zoe mentioned the "art teacher" many times when Zoe answered how she sought support while facing a difficulty for preparing art-integrated classes. These answers include "let me go check with our art teacher to make sure that I'm explaining it correctly", "I discuss with the art teacher", "I would go to our art teacher and have a discussion", "I pretty much either talking to our art teacher or …". Furthermore, I have observed how Zoe asked the art teacher for suggestions about the art integration and STEAM teaching plan. The art teacher Charles said that Zoe was constantly asking for his opinion and art material. Obviously, the data demonstrated that the art teacher is one of the main sources of Zoe's learning. Aside from the art teacher, Zoe spoke to "either another math teacher or coordinator or whoever [she] think[s] would be the most helpful in the situation" (Interview on May 11, 2023). Another source of Zoe's informal learning is STEAM department meetings and STEAM department's shared Google drive, where Zoe can seek for help and other teachers would give advice. Moreover, Zoe realized that discussing with others to find the solution can make a significant change for her future learning; she said, "talking [questions] through or getting that advice usually makes a big difference" (Interview on May 11, 2023). All the data above showed that Zoe communicated with the art teacher and other teachers in STEAM department when she needed suggestions. Hence, Zoe is more likely a social learner.

In the end of the interview on May 22, 2023, Zoe expressed that her summer trip in Greece "might […] end up in museums and galleries". Zoe never mentioned museums or galleries in the previous interviews, these places are ideal for individual

learners to informally learn art. These data indicated that Zoe probably combines both modes and exhibits an individual/social learner profile.

Zoe's Reactions to Dilemmas

According to Jurasaite-O'Keefe (2022), teachers differed in reactions to their teaching dilemmas when informal learners reacted exhibiting either their emotions, a mix of emotional/cognitive reactions, or reacted cognitively. Jurasaite-O'Keefe (2022) argued that emotional learners "seemed to be aware of their professional 'ups' and 'downs'… to reflect on their emotional states" (p.78). Other learners, however, reacted to problems that they encountered in a cognitive way. When describing their learning experiences, "they were specific in listing ideas and ways in which they could be useful in the future" (p.81), which places them as cognitive learners on the continuum. Emotional/cognitive learners replied to teaching dilemmas or other learning situations by applying both emotional and cognitive approaches in almost equal frequency.

Zoe said that the most difficult part for her in integrating arts is "make the connection" between mathematics and arts (Interview on May 11, 2023). In response to the dilemma, Zoe looked for help from the art teacher, asked other teachers in the STEAM meeting, and talked to the coordinator. In other words, Zoe tried as many means as she could to resolve her teaching predicaments. After discussions, Zoe asked herself, "how could I use this idea or this topic to kind of connect it to the math a little bit more?" (Interview on May 11, 2023). As the data demonstrated above, Zoe understood how to deal with the dilemma and how to bring the solution to improve her learning in the future. In addition, Zoe summarized every school year and reflected on her personal growth, as she said, "definitely at some point in August, I'll

sit down and kind of map out what worked this school year, what didn't work, and then try to find things to replace it if I need or kind of tweak certain activities we already have to better fit what [students'] need" (Interview on May 11, 2023). These data demonstrate that Zoe practices self-reflection, and she is preparing not only for dealing with possible teaching dilemmas, but also for improving her teaching to reduce the number of dilemmas by reflecting upon and learning from her "unsuccessful" experiences in the past school year. Hence, Zoe seems to exhibit features characteristic of a cognitive learner.

Zoe's Orientation to Problems for Learning

Jurasaite-O'Keefe (2022) states that orientation to problems for learning range in a continuum between self-oriented to teaching-oriented concerns. Three groups of learners are identified within this context, two on the extremes and one type in the middle of the field. These are the self-oriented learners, the self/teaching-oriented learners, and the teaching-oriented learners. Self-oriented learners are "concerned about personal rather than professional problems" (p.86). Teaching-oriented learners discuss their teaching dilemmas exclusively, and they "seemed to be looking for more than success in teaching" (p.91). Self/teaching-oriented learners focus on both professional and individual problems.

Zoe showed concerns with how to implement the STEAM lesson better. As the art teacher described, Zoe "always comes up to" him and asks, "is there a way that we can do something together?" (Interview on May 25, 2023). Zoe explained one reason why she prepared for the art-integrated class, "preparing, leading up to it, kind of ensures that I'm ready for what I'm gonna teach [students]" (Interview on May 11, 2023). During interviews and an observation of the meeting with the art teacher, Zoe

exclusively discussed her teaching difficulties instead of her personal problems. For example, during her cooperation with NASA, Zoe learned how to use the NASA application to upload the data to NASA, and then she taught students sending the data to NASA. Because Zoe is a teaching-oriented learner, she is willing to learn new knowledge for teaching and ensure students obtain a good understanding. Therefore, the data indicates that Zoe seems to be a teaching-oriented learner as well as an informal learner for the purpose of becoming a better teacher.

Zoe's Engagement in the Learning Process

Jurasaite-O'Keefe (2022) identified two opposite categories of learners based on their engagement in the learning process and one as the central point on the continuum, which are spontaneous learners, spontaneous/deliberate learners, and deliberate learners. Spontaneous learners are not looking for particular learning directions or not being aware of learning, they learn "from whatever comes along" (p.94). Deliberate learners participate in the learning process "striving to find out something specific in order to solve a dilemma that they faced at the moment" (p.98). Spontaneous/deliberate learners illustrate both characteristics of deliberate and spontaneous learners.

Zoe demonstrated awareness of dilemmas in the arts integration process, as she said, "finding a connection" between arts and mathematics is the most challenging time. Zoe explained, "sometimes once you find the connection, the activity is the easy part. Yeah. But to make the connection …" (Interview on May 11, 2023). Zoe mentioned that at the beginning of the art integration teaching, she saw "no connection to art for [mathematics]", however, she "really, really try[ed]" (Interview on May 11, 2023). To solve this problem, Zoe searched for resources online, asked the

art teacher, discussed with other teachers in the STEAM department, and talked to the coordinator. These multiple learning activities that she initiated demonstrated that Zoe made a conscious effort to deal with her teaching dilemma. In the observation of Zoe and the art teacher's meeting on June 12, 2023, Zoe prepared many art-integrated projects that she has researched online, and she showed all the projects to the art teacher to ask for advice. The art teacher described that Zoe "usually comes up with the basic ideas of what she wants to do, and then if she asks [him], it's usually about just execution of ideas…what do you think would be the best way to achieve this result or that result" (Interview with the art teacher on May 25, 2023). For example, during the meeting, Zoe asked the art teacher how to improve art projects or how to adjust art projects for students; before she met with the arts teacher, Zoe have developed her teaching plans. The data demonstrated that Zoe is not only solving emerging problems, but also preparing for the upcoming situations in advance. Therefore, Zoe seems to be a constantly growing deliberate learner.

Biology Teacher Erin

Erin's Background

Erin is a female high school biology teacher. She has been teaching biology for twenty-one years in total and eighteen years at this school. Furthermore, Erin is the director of the STEAM department, and she oversees organizing the STEAM department meetings and advising STEAM department teachers. Erin has a Master of Science in education. Presently, Erin is pursuing a Ph.D. in Curriculum and Instruction. Erin is an art admirer, and she loves appreciating paintings and various other types of artwork. Along with teaching biology, Erin is teaching a music class at the same school. In addition, she has been the organizer and founder of the school

musical play festival for two years. Moreover, Erin is a singer and a guitarist in a music band outside of the school. Erin is an experienced teacher who is passionate about bringing arts to mathematics and science; according to her, provides students with opportunities to have more enjoyable moments during mathematics and science learning.

Erin's Arts Integration Style

In this section, I will analyze and categorize Erin's arts integration teaching and learning style. Additionally, I will examine Erin's professional identity structure through the lens of arts integration styles' framework.

As I mentioned above, there are four styles of arts integration in science teaching and learning (Bresler, 1995). My interviews with Erin and observation of her teaching indicate that Erin's arts integration seems to belong to the co-equal, cognitive integration style. As the director of the STEAM department, Erin collaborates with the art teacher all the time. I observed Erin talking to the art teacher during the STEAM meeting, STEAM lessons planning, and any other times when her work needed the art teacher's advice.

For example, during a field trip that was organized by the STEAM department on May 8, 2023, I observed how Erin worked with the art teacher Charles to lead students in their implementation of art and science activities at a county park. In the beginning of the field trip, both teachers guided students to release four fish that were raised by students in the biology lab, into the river. Afterwards, Erin and Charles divided students into art and science groups as students chose it before the field trip. The art group students were drawing and painting by the river with Charles, science group students were observing and discovering nature with Erin. When I was drawing

with the art group students, one student wanted to draw a butterfly, hence Erin asked her to go to the science group to observe a butterfly before drawing. In the science group, Erin led students observing insects in the park with the assistance of the park's staff. After the lunch break, Erin and a park staff member, guided students in groups into the woods to observe trees, rocks, birds, and other objects and creatures in the nature. During this field trip, observation was the major skill that Erin was encouraging students to practice, that prepared them not only to be observant scientists but also artists keen on detail. In this case, art integration happened on the level of students' thinking – observing and taking in details like artists. Erin and the art teacher prepared and conducted the field trip and many other STEAM activities and lessons together.

Another example illustrated Erin's arts integration is under the co-equal, cognitive integration style. Before the STEAM lesson started, Erin discussed with the art teacher about their plans for other STEAM lessons. They also talked about the issue in the most recent STEAM lesson, in which the art teacher had a challenging time to learn to how use 3D printer for the three-dimensional artwork creating. These examples of cooperating with the art teacher to prepare and participate in STEAM meetings, the fieldtrip, STEAM lessons, and other STEAM activities indicate that Erin is more likely to use a co-equal, cognitive integration teaching style.

Examining Erin's Professional Identity Structure

In this section, I employ Beijaard et al. (2002) framework of four features of teachers' professional identity to analyze Erin's professional identity. They include teachers' experience, teachers' knowledge and attitude, teachers' sub-identities, and teachers' learning. In the following four paragraphs, I examine these features that

constitute Erin's identity structure through the lens of the co-equal, cognitive integration style.

Firstly, I will examine how Erin's experiences of arts integration framed her professional identity. Erin was the advocate of arts integration and STEAM education in the school, and she was the first teacher to ask the school to implement arts integration. Furthermore, Erin created a Google Drive for teachers from the STEAM department to contribute their art-integrated teaching plans to each other and organized the STEAM department teachers' meeting to present it. Erin was not only concerned with implementing arts integration in her own course, but also with the broad adaptation of STEAM education in the whole school.

Erin's knowledge and attitude seem to have formatted her professional identity. As a music teacher and musician, Erin loved both performing arts and visual arts, "I love this stuff: coloring and music. I have been doing this for over twenty years", she said on interview 4 on July 3, 2023. As a biology teacher, Erin wanted her students to "have fun" (Interview on July 3, 2023) in the biology class, and she believed that art is the best medium to fuse arts with science to deliver joy to students while they are learning. For example, in one of Erin's biology classes, Erin used candies to demonstrate normal and sick blood cells to students and asked them to create their own blood cells with candies (see Figure 6). As we know, blood cells only can be seen under the microscope. However, Erin utilized candies helping students seeing and understanding blood cells in a simplified way (Britannica, 2023). The candy blood cells is the sculpture. The media and shape of a sculpture varies and can include random "found" objects shaped and combined in different ways. Thus, Erin created the colored candy blood cells sculpture, and taught students to create their own candy

blood cells sculptures using different colors. By doing so, Erin helped students visualize the biology contents and let students enjoy the process of learning biology. She guided her students in using this genre of visual art in the biology lesson, which demonstrated her artistic thinking, which encompasses divergent, lateral, and creative thinking (D'Andrea, 2019). Because of Erin's passion for arts and her knowledge of biology and arts, Erin became a pioneer in practicing arts integration and STEAM education in her school.

Figure 6

Erin's Candy Demonstration of Normal and Sick Blood Cells under the Microscope

Erin seems to exhibit several sub-identities in the professional identity structure. As Erin said, "I had those ideas a couple of years ago, bringing the arts to my class, because I love it [arts]" (Interview on July 3, 2023). Furthermore, Erin mentioned that she is a singer and guitarist in a band, as Erin explained, "music is my thing" (Interview on July 3, 2023). For example, in the observation on May 3, 2023, Erin asked students to color the female reproduction on their handouts, and she instructed students to choose any color as long as it can make colors contrast; coloring in

contrast was the main art activity in this biology class. The concept of contrast of colors is from color theory in which Vladimir London (2023) explained that colors' contrast needs to be examined in colors' hue, temperature, values, and their way of influencing each other. By doing so, Erin integrated contrast of colors into the biology teaching, helping students to understand the distinct parts of the female reproduction system. In this case again, Erin employed artistic thinking when she brought the notion of colors' contrast.

Additionally, Erin mentioned a music class that she designed (interview on July 3, 2023). In that class, Erin asked students to throw sandbags on the musical notation made from a big plastic cloth a few times either randomly or purposefully. Consequently, students created their own simple melodies. Furthermore, Erin played every student's melody on the piano. These examples illustrate that Erin seemed to have two sub-identities: a musician and an art fancier and these two sub-identities led Erin to become a passionate arts integration and STEAM education advocate and practitioner.

Finally, I examine how Erin's professional identity is constructed through learning. Erin applied coloring in the class frequently. She reflected that she finds inspiration for this activity from a color theory, which she learned "from the school's arts class" (Interview on July 3, 2023). Additionally, Erin discussed her teaching activities with the art teacher Charles when she needed suggestions and new ideas. She said, "I work with the art teacher all the time" (Interview on July 3, 2023). Charles described, "we [Charles and Erin] just bounce things off of each other" (Interview on May 25, 2023). To learn more herself and encourage others to learn, Erin created a Google Drive for the STEAM department teachers to share teaching

ideas, so they can learn from each other. Erin is also the organizer of the STEAM department meetings in which she stimulates teachers learn from each by sharing their art-integrated projects and lesson plans. The data demonstrates that Erin employed various learning approaches for herself and the entire STEAM department teachers. As the director of the STEAM department, Erin sees arts learning as a common goal rather than a personal concern.

Erin's Informal Learning of Arts

In this section, I will employ Jurasaite-O'Keefe's (2022) framework of five aspects of teachers' informal learning, and analyze Erin's informal learning in terms of dispositions, sources, reactions, focus, and process.

Erin's Dispositions

As I mentioned above, Jurasaite-O'Keefe (2022) defined dispositions as points on the continuum along which a learner can be positioned; they are two extreme points -opportunistic learners and proactive learners, and a middle point of opportunistic/proactive learners. When observing the STEAM department meeting on June 12, 2023, Erin was the organizer and leader of the meeting. After Erin presented her new ideas of the art-integrated teaching, all teachers from the STEAM department shared their arts integration experiences with each other and planed art-integrated classes in groups. For the discussion, Erin joined a group of teachers, which included Zoe and the art teacher. During the group discussion, Erin took notes after she listened to other teachers' thoughts and stories of arts integration. After listening to everyone in the group, Erin shared her opinion. During the interview on July 3, 2023, Erin explained that the reason of taking notes during the STEAM meeting is "to remember their [teachers'] good ideas and to have more interesting things happen here". As the

director of the STEAM department, Erin is not only concerned with learning arts for her own teaching, but also willing to help other teachers to learn arts and integrate arts in their lessons.

During our personal talk on May 2, 2023, Erin showed me a drawing and a watercolor painting picture that she found online. Furthermore, Erin shared with me her thoughts about utilizing these two pictures for her teaching and asked if these two pictures would work in her art-integrated class. After our conversation, Erin created a teaching plan with her new understanding of these two pictures. Therefore, by evaluating what she needed to learn and planning for her learning in advance, Erin seemed to exhibit the characteristics of a proactive learner.

Erin's Source of Learning

Regarding sources of learning, Jurasaite-O'Keefe (2022) categorized three points on the continuum of informal learners, which include individual learners and social learners at its extreme points, and individual/social learners as a middle point. In the interview on July 3, 2023, Erin described how she worked with the art teacher in the past five years, as she said, "I always talk with the art teacher, and we figure out things together". In addition, when Erin and I shared our opinions of each other's recent arts integration research and the STEAM education projects, Erin said, "we have good time when we talk about these stuff". As I mentioned earlier, Erin created the STEAM department's Google Drive and organized the STEAM department meetings to "let teachers share and learn from each other, including myself", said Erin in interview on July 3, 2023. As the art teacher said, "[Erin] tries to get us to meet and kind of share ideas and spark ideas to collaborate in those meetings" (Interview on May 25, 2023). Thus, by interacting with others when she needed advice for the

planning and teaching, Erin displayed characteristics of a social learner.

In addition, Erin mentioned that she liked to browse museums' websites to look at arts online when she needs more inspiration for the arts integration class design. Erin appreciates artwork online frequently, and she "love[s] to go to museums and galleries if [she] got time", she said during our personal interaction on May 2, 2023. Furthermore, Erin liked to "check new art-science or math projects online to see if there's something […she] can learn" (interview on July 3, 2023). According to the data, Erin was not only communicating with others when she needed assistance, but also attempted to deal with the challenging situations on her own. Therefore, Erin displayed characteristics of both types of learners and is more likely an individual/social learner.

Erin's Reactions to Dilemmas

As I mentioned above, in accord with the teacher's reaction to dilemmas, Jurasaite-O'Keefe (2022) categorized three types of informal learners, they are emotional learners, emotional/cognitive learners, and cognitive learners.

In Interview on May 3, 2023, Erin shared a story that she was the first one to advocate the concept of arts integration and STEAM in the school. However, many teachers did not agree with her in the beginning. Eventually, Erin decided to implement arts integration in her biology class, as she said, "I thought I will do it [arts integration] by myself anyway" (Interview on July 3, 2023). Hence, Erin implemented arts integration in her biology class, and it was a success. The principal and other teachers noticed that students participated in Erin's class activities passionately and talked about Erin's biology class positively. Gradually, the school administration and other teachers started to support art-integrated classes and STEAM lessons, and the

school provided strong support after their cooperation with NASA. Erin's experiences of persisting in conducting arts integration gave her faith for arts integration and STEAM education, as she said, "I believe it [arts integration] will work" (Interview on July 3, 2023).

As I mentioned above, Erin taught students using candies to illustrate healthy and sick blood cells as candy blood cell sculptures. Indeed, this art-integrated design idea came from the difficult time of explaining biology learning in a vivid way. Erin attempted to let students gain comprehension "with more fun" (Interview on May 3, 2023). Hence, by knowing their teaching dilemmas and persisting in implementing arts integration in the school, Erin is likely to demonstrate the characteristics of a cognitive learner.

Erin's Orientation to Problems for Learning

Jurasaite-O'Keefe (2022) identified three points on the continuum of informal learners based on their orientations to problems for learning range. They are the self-oriented learners, the self/teaching-oriented learners on the extremes, and the teaching-oriented learners in the middle.

During my personal communication with Erin on May 2, 2023, and July 3, 2023, she mentioned many times the words "students", "kids", and "teaching", and Erin asked students to go to Google online classroom if they have questions after class. In my observation of the field trip on May 8, 2023, Ward Pound Ridge Reservation, Erin told me that she organized the field trip for providing students with an opportunity to understand biology knowledge by immersing in the nature. I observed that Erin paid attention to students and talked with the art teacher about students' activities planning. Furthermore, Erin directed students to walk into the woods to see natural objects, and she

gave instructions to students before they entered the woods. As the art teacher said in interview on May 25, 2023, "… [Erin] ask me, you know, what do you think would be the best way to achieve this result or that result for it [class]". Thus, by attempting to seek a better way for students comprehending biology learning, Erin seemed to be a teaching-oriented learner always trying to find out the best ways for students to learn.

Erin's Engagement in Learning Process

In the observation on May 11, 2023, I saw that Erin was using a "Formstruction Set" and color push pins to illustrate DNA. She folded the "Formstruction Set" with various push pins to show the folding protein structure and key in DNA (see Figure 7). The DNA demonstration model that Erin has created is a sculpture. By doing so, Erin utilized the art form of sculpture to demonstrate difficult information to students. And again, Erin applied her artistic thinking to represent a complex concept of DNA structure. Not only she was creative in choosing the most vivid way to represent the concept, but she acted as an artist when adjusting the modality and material for crafting a sculpture.

During our personal communication on May 2, 2023, Erin explained the reason to implement this activity in the class - because she was longing for bringing more advanced biology learning to the class. At the same time, Erin was willing to integrate arts into the teaching that brought students' thinking to a higher level. Indeed, this curriculum was originally designed for college students. However, Erin believed that it was ideal for her students to understand the content. Students demonstrated their understanding of the content by creating their own DNA demonstration models after Erin's example and explanations. She was successful by teaching it this way.

Figure 7

Erin's Demonstration of Folding Protein Structure and Keys in DNA

In addition, Erin likes to browse museums and art projects online; brainstorming with the art teacher; read and listen to other teachers' art-integration class plans via Google Drive and the STEAM department meetings. According to the data, by learning arts both with purpose and without thinking about a specific goal, Erin seems to demonstrate characteristics of a spontaneous/deliberate learner.

Conclusion

In conclusion, both Zoe and Erin are art-integrated teachers. Zoe implemented arts integration under two styles: the co-equal, cognitive style, and the social integration style. Zoe structured her professional identity via experiences, knowledge and attitude, learning, and two sub-identities: a mathematics teacher who is not good at arts, and a math games lover and practitioner. Furthermore, these characteristics allow Zoe to resolve her teaching dilemmas as a proactive learner, a social learner, a

cognitive learner, a teaching-oriented learner, and a constantly growing deliberate learner.

In the observations of both teachers, Zoe applied watercolor painting and mathematics games to the mathematics teaching, in many instances, Erin utilized sculpture in the biology classes. During the arts integration process, Zoe worked with the art teacher and received support from the art teacher to implement art-integrated classes, such as the watercolor painting STEAM lesson. Zoe utilized math games when she was not collaborating with the art teacher. However, Erin designed the art-integrated biology teaching plan by herself and conducted it through the creative activities: creating the candy blood cells and DNA demonstration model sculptures.

Erin's arts integration follows the co-equal, cognitive integration style patterns. Erin has two sub-identities; the musician's and the arts fancier's. Furthermore, as an art informal learner in five aspects, Erin is likely to be a proactive learner, an individual/social learner, a cognitive learner, a teaching-oriented learner, and a spontaneous/deliberate learner, who understands her learning dilemmas and makes efforts for solving the problems actively and in a timely manner.

Nonetheless, Erin needs to continue learning to integrate arts in teaching biology. For example, she could have implemented better arts integration activities during the field trip on May 8, 2023, at Ward Pound Ridge Reservation. Erin could have introduced the eco-system of the park to students in advance, and then asked the art teacher to guide students drawing or painting the park's eco-system in groups. There is a lot of potential to improve the art-integrated activities during field trips in the future.

As art-integrated teachers, Zoe and Erin applied art for provoking interest,

curiosity and higher order thinking. However, their applied integration differently. Zoe worked closely with the art teacher on the watercolor painting STEAM lesson, whereas Erin was able to design and create art activities on her own, which demonstrated her creativity and independent thinking. The difference between Zoe's and Erin's implementation of art-integrated teaching could be explained by Zoe's lack of artistic thinking and Erin's strong presence of artistic thinking (Costes-Onisshi, 2019; D'Andrea, 2019), which, at the same time, evoked students' artistic thinking. Artistic thinking enabled Erin to immerse students in making art during the arts integration process. It also empowered Erin to be an innovative arts integration designer and implementor.

CHAPTER 6 DISCUSSION AND LIMITATIONS

In this chapter, I will discuss how my findings relate to the current research in this area. I will focus on teachers' artistic thinking and its potential for developing art-integrated teaching. In addition, I will examine the limitations of my research.

Discussion: Developing Art-integrated Teachers' Artistic Thinking

My major finding on the importance of artistic thinking for art-integrated STEAM teaching guided me to reexamine literature on STEAM or art-integrated teachers' development (Clandinin, & Huber, 2005; Connelly & Clandinin, 1999; Conway, 2001; Fenstermacher, 1994; Florio-Runane, 2000; Korthagen, 2001; Lampert, 1985; 2001; Malcolm et al., 2003; Richardson & Fallon, 2001; Shulman, 1987; Zeichner, 1998), teachers' professional identity development (Beijaard et al., 2002, 2004, 2012; Canrinus et al., 2011; Fuller et al., 2013; Pillen et al., 2012; Rus et al, 2013, Timostsuk, & Ugaste 2010; Vahasantanen et al., 2008), and support teachers receive from art programs or art teachers (Davis, 2010; Grant & Patterson, 2016; Hunter-Doniger & Sydow, 2016; Plonczak & Zwirn, 2015; Trimble, 2019; Wells & Wagner, 2013; Wylder et al., 2015). Surprisingly, none of these studies acknowledge the influence and importance of artistic thinking for STEAM or art-integrated teachers.

Recently discussed by D'Andrea (2019), artistic thinking is "a playful concept that will allow you to avoid a reductive or limited approach to thinking that lacks rigour and produces paralysis in your thoughts…telling you not to pursue your passion…" (p.3). Artistic thinking drives teachers on the art journey, so that they keep practicing and creating arts no matter what roadblocks they encounter in the process. Moreover, artistic thinking allows people to think freely. D'Andrea (2019) depicts seven stages in the development of artistic thinking, the first stage is passion and obsession, the second stage is imagining and

believe, the third stage is observe and connect, the fourth stage is visualize and ponder, the fifth stage is learn and explore, the sixth stage is practice and repeat, and the last stage is self-transform and innovative. These stages are important to consider as they lead to teaching innovations – a result that is highly looked for in any educational reform.

According to D'Andrea, artistic thinking starts with passion and ends with innovation. Science teacher Erin demonstrated a great passion for the arts. In her use of creative thinking, she passed through the other six stages and guided students to create sculptures in a biology class, which innovated her STEAM teaching. Nonetheless, Zoe lacked passion for the arts and seemed to lack artistic thinking. She struggled to integrate arts and instead applied math games to replace creative art-related activities for the mathematics class. Her lack of passion for arts was evident when she admitted that she did not visit art museums and galleries, though she planned on doing it in the summer. With all her efforts to integrate arts into her teaching, she never entered the first stage of artistic thinking.

As an artist and art fan, I believe that someone who likes art is more likely to seek art-related activities. However, Zoe seemed to participate in arts integration and STEAM education because of the school's decision instead of her passion for arts. Because of a lack of passion for arts, Zoe had difficulty implementing arts integration. Zoe's math class on May 11, 2023, included a math game. However, there was no art involved in it. As Zoe mentioned earlier, her challenge of implementing arts integration was finding the connection between arts and math. Obviously, Zoe could not build the connection for this class. Even though Zoe has cooperated with the art teacher for five years, she still was not able to prepare and implement art-integrated mathematics class independently. If Zoe gains passion for arts and starts thinking artistically, it is more

likely to build the connection and design arts integration class with innovation. Thus, stimulating Zoe's passion for arts could help her in the arts integration process.

As Costes-Onishi (2019) explains, "learners would acquire the habits of mind to lend aesthetic quality to all their experiences inside and outside of the art classrooms and thereby achieve lifewide, lifedeep and lifelong learning" (p.300). Stimulating teachers' passion for art needs to set teachers' habits of mind to think artistically. To develop these habits, teachers should have art experience inside and outside of the school, so that they are able to start learning arts and develop a passion for arts.

In Erin's case, she was passionate about integrating arts into her biology teaching in various ways, and she tried to apply artmaking in the biology class to deepen students' learning. Erin is so passionate about arts integration that she is an inspiration for arts integration for the whole school. During the field trip on May 8, 2023, however, Erin could have designed more developed art-biology integrated activities, such as organizing both art and science groups of students drawing together by depicting the ecosystem of the park. Instead, Erin and the art teacher guided the art students' and the science students' groups separately. They could have brought them together to express biology concepts by means of art. Even though the art teacher and Erin collaborated on the field trip, the field trip was less innovative than Erin's art-integrated biology classes, lacking artistic thinking in its implementation.

To sum up, the findings demonstrate that art-integrated teachers not only need art professionals to assist with curriculum preparation. The development of artistic thinking needs to be put in the center of preparation for arts integration. The informal learning of arts might lead to expanding and deepening the comprehension of the art and its aesthetic value that, in turn, could ignite the development of artistic thinking,

which will lead to arts integration implementation more innovatively and independently.

Limitations

As I conducted this study, I distinguished several limitations. In this section, I will employ Lincoln and Guba's (1985) quality criteria for trustworthiness to assess my study's limitations. Based on Lincoln and Guba (1985), Alexander (2019) discusses four criteria for qualitative inquiry, which are credibility, dependability, confirmability, and transferability.

Firstly, credibility carries out "the study in a way that enhances the believably of the findings" and "taking steps to demonstrate credibility to external readers" (Alexander, 2019, "Credibility" section). There are six techniques for building credibility, which include prolonged engagement, persistent observation, triangulation, peer debriefing, negative case analysis (deviant case analysis), and member-checking. I collected data for my study from May 2023 to July 2023 at a high school. I observed both the math teacher's and biology teacher's classes, and I applied the method of triangulation, which included cross-analyzing interviews, observations, and artifacts. In the meantime, I implemented a member-check with Erin to provide feedback and obtain her reactions. I also applied negative case analysis (deviant case analysis) during the research process. The negative case analysis is that Zoe utilized math games when she could not apply arts integration for her math lessons, and math group students and art group students did not participate in art-related activities together during the field trip. In addition, I conducted oral summaries of peer debriefing to examine my data analysis process.

The prolonged engagement criteria, which requires the researcher to establish rapport and trust with participants, which is more likely to gain rich data for the study,

was difficult to implement as I had only this much time to spend in the school and collect my data. Nonetheless, I talked with Erin on multiple occasions during my research process because we have known each other for several years and have developed a trusting and supportive relationship. Along with two interviews with Erin, I was involved in personal communication with her, the chats before and after the biology class, chats during the field trip, and many other conversations beyond school settings. I felt that I understood Erin's thoughts on arts integration and her professional identity structure deeper and broader than Zoe's. I believe that my engagement with Erin and Zoe was not equal; unfortunately, I built less trust with Zoe, and thus I obtained less rich data from Zoe. This limitation of my study might have constrained my interpretation of Zoe's identity.

Secondly, dependability is crucial to credibility, and the only technique to establish dependability is an inquiry audit. For my research, the data was scrutinized by applying NVivo for coding in addition to hand-coding. By doing this, the data was impartially audited.

Thirdly, confirmability can be established by three techniques, they are audit trail, triangulation, and reflexivity. I built triangulation by analyzing three sources of data which are interviews, observations, and physical artifacts. Additionally, I used reflexive journaling that served to adjust my interview questions and observation focus points during the data collection process. To apply an audit trail, the researcher needs to let an auditor make a conclusion about the data including six aspects of records. They include the raw data, data reduction, and analysis products, process notes, materials relating to researchers' intentions and dispositions, instrument development information, and data reconstruction products. Unfortunately, I

implemented six steps of the audit trail by myself instead of asking an independent auditor. Therefore, lacking an audit trail became one of my research limitations.

Finally, transferability refers to the researchers' responsibility of providing readers with adequate descriptive data, for the purpose of readers' positive comprehension of data. To establish transferability, the research needs a thick description. I believe that I described my research context in detail to help readers understand my study. However, on the level of providing sufficient data, my "insider's" perspective limited the scope of my observations. According to Fossey et al. (2022), the researcher's lens of "insider" or "outsider" may vary in different studies during the observation, and "some degree of participation and persistent engagement are essential if the complexities of meanings and situations are to be adequately explored and uncovered" (p.727). In other words, to be an insider is important for an observer to uncover nuances of the phenomenon at hand.

In many cases in this study, I was deeply submerged in the observations and interviews as an insider to the processes of arts integration – a math teacher, who is also a visual artist and an art fancier, who has integrated arts in teaching. For example, the field trip on May 8, 2023, I observed as an insider. I was painting by the river with the art group students, and I was appreciating their artwork too, I enjoyed the entire field trip with both teachers and students. However, I did not have a chance to observe the science group students' activities because I was deeply immersed in the art group. Being an insider participant observer has limited me in gaining a critical view of the whole field trip that included both art students' and science students' participation. In this case, I could not see how the biology teacher-led science group students implemented their activities. Thus, as an insider of the art students' group in the observation of the field

trip, I could not provide sufficient data on the field trip, which is one of the limitations of my research.

CHAPTER 7 IMPLICATIONS AND CONCLUSIONS

Implications

In this section, I will discuss the implications and contributions of my research, which encompass implications and contributions for teachers, policymakers, and researchers. Additionally, I will explain a potential my study opens future research, and what improvements of the future research can be made.

Firstly, my research findings show that artistic thinking is critical to mathematics and biology teachers' arts integration teaching. Hence, the school could organize some events to stimulate teachers' artistic thinking. For instance, organizing teachers to visit museums or galleries to create opportunities for enjoying and discussing art. What is more, Robbins and Sandberg (2023) suggest seven steps for teachers learning to begin thinking artistically, which start from "making your process more playful" and end with "think with your body" (p. 15). In the future, Erin could employ these seven steps when she is organizing the STEAM meeting, so that teachers' artistic thinking can be stimulated for preparing art-integrated classes by conducting these seven steps.

Secondly, policymakers could use this study to re-consider how to provide support to art-integrated teachers and STEAM schools for developing teachers' artistic thinking. In addition to supporting or funding STEAM schools and art projects in schools, policymakers can make policies to encourage schools to assist math and science teachers in building artistic thinking, rather than depending on art specialists to explain everything in art projects. For example, stimulating schools' collaboration with museums by introducing artwork and telling art stories, to expand teachers' comprehension of art and inspire teachers' artistic thinking. What is more, by engaging teachers in arts integration and learning more, policymakers should call for

more art-math or art-science cooperation programs, such as my research school and NASA's science projects.

Thirdly, researchers might want to examine disconfirming evidence (negative case analysis) of art-integrated research projects and ask questions such as if there are other ways to implement arts integration when artistic thinking is absent. During my research, I did not find evidence to answer positively to these questions. These questions could lead to more future research. For example, examining examples of effective practice of arts integration and creating a handbook by listing many examples so that teachers could follow positive examples for carrying on arts-integrated teaching.

In addition, future research could go beyond the limitations of this study and implement other research designs. Using an ethnographic approach and obtaining equal prolonged engagement with each participant could call for more time conducting research, which would include collecting more interviews, personal conversations, observations, and artifacts and provide an opportunity for a deeper understanding of arts integration. Moreover, implementing the audit trail to strengthen the trustworthiness of the research, and raising the awareness of "insider" and "outsider" perspectives for interpreting data would make research more transferable.

Conclusion

In conclusion, I conducted qualitative research for my dissertation by analyzing interviews, personal conversations, observations, and physical artifacts. I explored high school science and high school mathematics teachers' professional identities' development during the arts integration process.

During my research, I employed a newly-developed conceptual framework to examine science and mathematics teachers' professional identities' development during arts integration (see Figure 1). Simultaneously, to ground my research from both psychological and philosophical aspects, I applied Vygotsky's social-cultural theory and Greene' theories of the arts and imagination.

For my findings, the data indicate that the math teacher Zoe's arts integration seems to compass two styles: the co-equal, cognitive integration style, and the social integration style. Additionally, Zoe's professional identity is an art-integrated mathematics teacher who is passionate about helping students, and her sub-professional identity is more likely to be a mathematics teacher who is not good at arts. Zoe is not an art fan, neither is she an art practitioner. By analyzing Zoe's informal art learning, Zoe is a proactive learner, a social learner, a cognitive learner, a teaching-oriented learner, and a constantly growing deliberate learner when resolving her teaching dilemmas. However, her learning to resolve teaching dilemmas seems to be directed into including more games rather than arts. When applying the concept of artistic thinking in successful arts integration, she seems to have lacked artistic thinking which caused her to struggle with arts integration.

The data demonstrates that Erin's arts integration is more likely to be the co-equal, cognitive integration style. Erin seemed to have two sub-identities: a musician and an art fan. Her professional identity is more likely to be a passionate arts integration and STEAM education advocate and practitioner. As an art informal learner, Erin is likely to be a proactive learner, an individual/social learner, a cognitive learner, a teaching-oriented learner, and a spontaneous/deliberate learner. The data also demonstrate that artistic thinking plays a significant role in Erin's arts integration implementation. In contrast to

Zoe, who could not design art-integrated teaching independently due to the absence of artistic thinking, Erin seemed to have no trouble integrating arts into teaching biology as she created sculptures for biology class. This finding is highly important as it fills the existing gap in literature emphasizing the significant role that teachers' artistic thinking plays in arts-integrated teaching. Therefore, the discussion focuses on stimulating and developing teachers' artistic thinking.

The limitations in my research also prompt some advantages of other research designs such as ethnography, the study could have benefitted from my prolonged and more balanced engagement with Erin and Zoe, an audit trail, and more data on the field trip.

Ultimately, the implications of my study draw the attention of teachers, policymakers, and researchers in developing teachers' artistic thinking for implementing arts integration teaching. The limitations and implications could be used in future research focused on the development of artistic thinking.

APPENDIX A

INTERVIEW QUESTIONS SEMI-PROTOCOL FOR STEAM OR ART-INTEGRATED TEACHERS

My name is Lulu Sun and I am a Ph.D. student in the Department of Curriculum and Instruction at St. John's University. My research is focused on STEAM or arts-integrated teachers' arts informal learning experience, and I am particularly interested in understanding teachers' self-identity development during this experience. Below is an interview for STEAM or Arts-integrated Teachers.

Introduction: Thank you for meeting with me to discuss arts informal learning. I would like to ask you a few questions to learn about your arts informal learning experience and your self-identity development. You do not have to answer any questions if you do not want to and you can discontinue this interview at any time.

Do you have any questions before we begin?

1. Which subject do you teach? How long have you taught this subject? What grade do you teach?
2. How long have you been a STEAM teacher / an art-integrated teacher?
    a. Can you tell me why you became a STEAM teacher/or an art-integrated teacher? How do you feel about it?
3. Do you like/ or believe in arts?
    a. How do you think arts can help with your class? Have you found any difference before and after art integrated into your class?
4. How does your school support you?
    a. How would you like to be supported more by your school?
5. What's your resource to learn/or know arts? How do you learn arts by yourself?

6. What's the difference between learning arts and teaching with arts?
7. Would you like to share your challenging experience in learning arts?
    a. When you feel a lack of confidence in arts, how did you adjust yourself?
    b. If it can, what do you think the school can support you with this?

Lastly, would you like to share a story of when you feel enjoyment of learning arts or teaching classes by using the arts?

REFERENCES

Alexander, A. P. (2019). *Lincoln and Guba's quality criteria for trustworthiness.* IDC International Journal. https://idcinternationaljournal.com/0ct-2019/Article_6_manuscript_IDC_August_October_2019_Dr_Annie_full.pdf

Aprill, A. (2010). Direct instruction vs. arts integration: A false dichotomy. *Teaching Artist Journal, 8*(1), 6-15. http://doi.org/10.1080/15411790903393004

Beijaard, D., Meijer, P., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and Teachers Education, 20*(2), 107-128. http://doi.org/10.1016/j.tate.2003.07.001

Bequette, J. W., & Bequette, M. B. (2015), A place for art and design education in the STEM conversation. *Art Education, 65*(2), 40-47. http://doi.org/10.1080/00043125.2012.11519167

Bresler, L. (1995). The subservient, coequal, affective, and social integration styles and. their implications for the arts. *Arts Education Policy Review, 96*(5), 31-37. http://doi.org/10.1080/10632913.1995.9934564

Cahnmann-Taylor, M., & Sanders-Bustle, L. (2019). Art-informed pedagogies in the preparation of teachers in the United States, *Oxford Research Encyclopedias.* http://doi.org/10.1093/acrefore/9780190264093.193.376

Canrinus, E., Helms-Lorenz, M., Beijaard, D., Buitink, J., & Hofman, A. (2011). Profiling teachers' sense of professional identity. *Educational Studies, 37*(5), 593-608. http://doi.org/10.1080/03055698.2010.539857

Clandinin, D.J., & Huber, M. (2005). Shifting stories to live by. In *Teacher professional development in changing conditions* (pp. 43-59). Springer.

Costes-Onisshi, P. (2019). Conclusion: Evidences of artistic thinking in the schools. In

Artistic thinking of schools (pp. 299-309). ResearchGate. http://doi.org/10.1007/978-981-13-8993-1_16

Connelly, F.M., & Clandinin, D.J. (Eds.). *Shaping a professional identity: Stories of educational practices.* Teachers College Press.

Conway, P. F. (2001). Anticipatory reflection while learning to teach: From a temporally truncated to a temporally distributed model of reflection in teacher education. *Teaching and Teacher Education, 17*, 89-106.

Creswell, J.W., & Poth, C.N. (2018). *Qualitative inquiry research design: Choosing. among*. five approaches (5th ed.). Sage.

Cruzes, D., Dyba, T., Runeson, P., & Host, M. (2011, September 22-23). *Case studies synthesis: Brief experience and challenges for the future* [Conference session]. Proceeding of the 5th International Symposium on Empirical Software Engineering and Measurement, Banff, AB, Canada. http://10.1109/ESEM.2011.44

D'Andrea, M. (2019). *The power of artistic thinking: Think like an artist and innovate.* Common Ground Research Networks.

Davis, H. J. (1999). Nowhere, somewhere, everywhere: The arts in education. *Arts Education Policy Review, 100*(5), 23-28. http://doi.org/10.1080/10632919909599472

Encyclopedia Britannica. (2023, October). *The arts.* https://www.britannica.com/search?query=The%20arts

Erikson, E. H. (1968). *Identity, youth and crisis.* W.W. Norton & Company.

Ewing, R. (2010). *The arts and Australian education: Realising potential*. Australian Council for Educational Research.

Fenstermacher, G. D. (1994). The Knower and the Known: The Nature of Knowledge in Research on Teaching. In L. Darling Hammond (Ed.). *Review of Research in Education, 20.* American Educational Research Association.

Florio-Ruane, S. (2000). *Teacher education and the cultural imagination: Autobiography, conversation, and narrative.* Lawrence Erlbaum Associates.

Fossey, E., Harvey, C., Mcdermott, F., & Davidson, L. (2022). Understanding and evaluating qualitative research. Australian and *New Zealand Journal of Psychiatry, 36*(6), 717-732. https://doi.org/10.1046/j.1440-1614.2002.0110

Fuller, C., Goodwyn, A., & Francis-Brophy, E. (2013). Advanced skills teachers: professional identity and status. *Teachers and Teaching, 19*(4), 463-474. http://doi.org/10.1080/13540602.2013.770228

Ginsburg, H.P., & Opper, S. (1988). *Piaget's theory of intellectual development.* Prentice Hall.

Grant, J., & Patterson, D. (2016). Innovative arts programs require innovative partnerships: A case study of STEM partnering between an art gallery and a natural history museum. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 89*(4-5), 144-152. http://doi.org/10.1080/00098655.2016.1170453

Green, K., Trundle, K. C., & Shaheen, M. (2018). Integrating the arts into science. teaching and learning: a literature review. *Journal for Learning through the Arts, 14*(1). https://doi.org/10.21977/D914140829

Greene, M. (1995). *Releasing the imagination.* Jossey-Bass Publishers.

Gullatt, D. (2008). Enhancing student learning through arts integration: Implications for the profession. *The High School Journal, 91*(4), 12-25.

Hallinen, J. (2021, November 18). *STEM.* Encyclopedia Britannica. https://www.britannica.com/topic/STEM-education

Hunter-Doniger, T., & Sydow, L. (2016). A journey from STEM to STEAM: A middle school case study. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 89*(4-5), 159-166. http://doi.org/10.1080/00098655.2016.1170461

Jonelle, P., Charles, D., & Ken, P. (2011). Arts integration in teacher preparation: Teaching the teachers. *Journal of Learning through the Arts, 7*(1), 1-11. http://doi.org/10.21977/D97110004.

Jones, W. M., & Dexter, S. (2014). How teachers learn: the roles of formal, informal, and independent learning. *Educational Technology Research and Development, 62*, 367-387.

Jurasaite-Harbison, E., & Rex, L. A. (2013). Teachers as informal learners: Workplace professional learning in the United States and Lithuania. *Pedagogies, 8*(1), 1-23.

Jurasaite-O'Keefe, E. (2022). *Individual, school. And national factors impacting teachers' workplace learning: Discourses of informal learning in north America and Lithuania.* Routledge Research in teacher Education.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry. Sage.*

Stake, R.E (1995). *The art of case study research*. Sage.

Stake, R.E (2006). *Multiple case study analysis.* Guilford Press.

Tellis, W.M. (1997). Application of a case study methodology. *The Qualitative Report, 3*(3), 1-19. https://doi.org/10.46743/2160-3715/1997.2015

Levy, S. (1988). *Information technologies in universities: An institutional case study.* Unpublished doctoral dissertation, Northern Arizona University, Flagstaff.

Khinkanina, A. (2014). The importance of Lev Vygotsky's theory of art for the. formation of modern ideas of child development. *International Journal of Psychological Research, 7*(2), 85-91.

Korthagen, F. (2001). Learning from practice. In *Linking practice and theory: The pedagogy of realistic teacher education* (pp. 20-50). Lawrence Erlbaum Associates.

Kremer, L., & Hofman, J, E. (1985). Teachers' professional identity and burn-out. *Research in Education, 34*(1), 89-95.

Lampert, M. (1985). How Do Teachers Manage to Teach? Perspectives on Problems in Practice. *Harvard Educational Review, 55*(2), 18-35.

Land, H, M. (2013). Full STEAM ahead: The benefits of integrating the arts into STEM. *Procedia Computer Science, 20,*547-552. http://doi.org/10.1016/j.procs.2013.09.317

Lindqvist, G. (2010). Vygotsky's theory of creativity. *Creativity Research Journal, 15*(2), 245-251.

Malcolm, J., Hodkinson, P., & Colley, H. (2003) The interrelationships between informal and formal learning. *Journal of Workplace Learning, 15*(7 / 8), 313-318.

Merriam, S.B. (1990). *Case Study Research in Education: A Qualitative Approach* (3rd ed). Jossey-Bass Inc.

Miller, D. R. (1962). The study of social relationships: Situation, identity, and social interaction. In S. Koch (Ed.), *Psychology: A study of a science. Study II: Empirical substructure and relations with other sciences*: *Vol. 5. The process areas, the person, and some applied fields: Their place in psychology and in*

science (pp. 639–737). McGraw-Hill. https://doi.org/10.1037/10040-010

Mishler, E.G. (1999). *Storylines: Craft artists' narratives of identity.* Cambridge, MA: Harvard University Press.

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature Review. *Thinking Skills and Creativity, 31*(3), 31-43. http://doi.org/10.1016/j.tsc.2018.10.002

Pille, M., Beijaard, D., & Brok, P. (2013). Tensions in beginning teachers' professional identity development, accompanying feelings and coping strategies. *European Journal of Teacher Education, 36*(3), 240-260. http://dx.doi.org/10.1080/02619768.2012.696192

Plonczak, I., & Zwirn, S. G. (2015). Understanding the art in science and the science in art through crosscutting concepts. *Science Scope*, 58-63.

Polin, S. (2015). Full STEAM ahead: Education students develop custom exhibits. proposals for Herreshoff Marine Museum. *The Week at Roger.* https://docs.rwu.edu/weekatroger_featured_news/538/

Reck, B., & Wald, K. M. (2018). Toward a signature pedagogy for arts integration in educator preparation. *Pedagogies: An International Journal, 13*(2), 106-118. http://doi.org/10.1080/1554480X.2018.1453364

Rehm, M., & Notten, A. (2015). Twitter as an informal learning space for teachers? The role of social capital in Twitter conversations among teachers. *Teaching and Teacher Education, 60*, 215-223. http://doi.org/10.1016/j.tate.2016.08.015

Richardson, V., & Fallon, C. (2001). Classroom Management as Method and Manner. *Journal of Curriculum Studies, 33*(6), 705-728.

Robbins, P., & Sandberg, B. (2023). Art thinking: amplifying the 'R' in R&D – letter

from America. *Journal of Innovation Management, 11*(1), 9-21. https://doi.org/10.24840/2183-0606_011.001_L002

Rus, C. L., Tomsa, A. R., Rebega, O. L., & Apostol, L. (2012). Teachers' professional identity: A content analysis. *Procedia – Social and Behavioral Sciences, 78*(13), 315-319. http://doi.org/10.1016/j.sbspro.2013.04.302

Shapiro, J. K. (2003). *Exploring teachers' informal learning for policy on professional development* (Publication No. 3059119) [Doctoral dissertation, The RAND Graduate School]. ProQuest Dissertation Publishing.

Shuell, T. J. (1986). Cognitive conceptions of learning. *Review of Educational Research, 56*(4), 411-436. http://doi.org/10.3102/00346543056004411

Shulman, L. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review, 57*(1), 1-22.

Silverstein, L. B., & Layne, S. (2010). What is arts integration? Defining arts integration. The John F. Kennedy Center for the Performing Arts. https://www.kennedy-center.org/education/resources-for-educators/classroom-resources/articles-and-how-tos/articles/collections/arts-integration-resources/what-is-arts-integration/

Snyder, L., Klos, P., & Grey-Hawkins, L. (2014). Transforming teaching through arts integration. *Journal for Learning through the Arts, 10*(1), 1-24. http://doi.org/10.21977/D910119308

Tellis, W. (1997). Introduction to case study. *The Qualitative Report, 3*(2), 1-14.

Timostsuk, I., & Ugaste, A. (2010). Student teachers' professional identity. *Teaching and Teacher Education, 26*(8), 1563-1570. https://doi.org/10.1016/j.tate.2010.06.008

Trimble, S. (2019). Weaving the arts into math curriculum. *Teaching Artist Journal, 17*(1-2), 62-65. http://doi.org/10.1080/15411796.2019.1595977

Vahasantanen, K., Hokka, P., Etelapelto, A., Radku-Puttonen, H., & Littleton, K. (2008). Teachers' professional identity negotiations in two different work organisations. *Vocations and Learning*, 131-148. http://10.1007/s12186-008-9008-z

Vygotsky, L. S. (1971). The psychology of art. MIT Press. (Original work published 1925)

Vygotsky, L. S. (1978). Mind in society. Harvard University Press.

Vygotsky, L. S. (1995). Fantasi och kreativitet i barndomen [Imagination and creativity in childhood]. Daidalos. (Original work published 1930)

Wells, B., & Wagner, P. (2013). The fusion project: bridging the art museum and the middle school math classroom. *Journal of Mathematics and the Arts, 00*(00), 1-16. http://doi.org/10.1353/hsj.0.0001

Whitehead, D. (2004). The pedagogical aesthetic and formative experience: Educating for *aletheic* imagination in the fine arts curriculum. *Journal of Visual Art Practice, 3*(3), 195–208. https://doi.org/10.1386/jvap.3.3.195/0

Wynn, T., & Harris, J. (2015). Toward a stem + arts curriculum: creating the teacher team. *Art Education, 65*(5), 42-47. http://doi.org/10.1080/00043125.2012.11519191

Wylder, V. D., Lerner, E. B., & Ford, A.S. (2014). Elementary reflections: case study of a collaborative museum /school curatorial project. *Journal of Museum Education, 39*(1), 83-95. http://doi.org/10.1080/10598650.2014.11510798

Yin, K.R. (2012). *Applications of case study research.* Sage.

Yin, K.R. (2014). *Case study research design and methods* (5th ed.). Sage.

Zeichner, K. M. (1998, June 2-4). *The role of practitioner research in personal, educational, and social reconstruction.* Paper presented at the Conference on Action Research (Aksjonforskining), University of Tromso, Norway.

Vita

Name	*Lulu Sun*
Baccalaureate Degree	*Bachelor of Arts in English, Hainan Normal University, Haikou, Hainan, China, Major: English Education*
Date Graduated	*July, 2005*
Other Degrees and Certificates	*Master of Arts Administration, Central Queensland University, Sydney, Australia, Major: Arts Administration*
Date Graduated	*July, 2007*
Other Degrees and Certificates	*Master of Arts in Journalism, University of Technology Sydney, Sydney, Australia, Major: Journalism*
Date Graduated	*July, 2009*