

“Grandma says I am a little scientist.” Apprenticeship, Photo-Storytelling, and Identity

A Science Educator's Culturally Situated Auto-Ethnographic Family Case Study

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Abstract

To participate in everyday STEM (Science, Technology, Engineering, Math) and perhaps aspire to be a STEM professional, children need to develop a “STEM person” identity as welcome and capable investigators. This identity development can begin at home where a family lives its culture of values, attitudes, and interests. In this two and half year case study, I used auto ethnography to explore my dual identities as a science educator and grandmother to guide my granddaughter’s explicit early STEM identity development as she baked Sabbath bread with me. I modeled and mentored her through activity, conversation, and a photobook/reading technique. The book became a memory support and an identity artifact as a record of what we did. It also allowed for her voluntary revisiting of the experience to repeat the storytelling of herself as an emergent, able STEM participant. The study suggests that I did contribute to my granddaughter’s science identity development, learning to adapt to her growth. The photo stimulated storytelling, now readily available to most families, might be a transferable technique to support STEM identity building in welcoming children into our community of practice as everyday scientists. Critically, family photos are images of a family’s culture, as were mine.

Keywords: science identity development, family science, science storytelling, photobooks and science, family science identity

Introduction

I studied my dual identities of grandmother and professional science educator to explore how one granddaughter and I interact to welcome her into a “science person” identity, focusing on a relevant and culturally specific baking activity in our family environment. By using an auto-ethnographic case study method, I examined my practices with Toby (pseudonym) looking closely at how I encourage her to participate in a community of people recognizing the opportunities to observe, use common tools, collect data, and discuss findings in our everyday activities. This community includes science educators like me, but also families who recognize and encourage each other to be aware of science as a way of knowing (Bell, 2009; Dewitt et al., 2012; Herbert, 1980; Solis & Callanan, 2018). My identity as science educator includes the sharing of science education practices. In this case, I reflected upon what it is that many families do in common. We all need to eat, which makes kitchen science an accessible area of intergenerational science mentoring (Harbison, 1997; NSTA, 2009, Partridge, 1986; Tunnicliffe & Gkouskou, 2019; Zubrowski, 1981). I chose to use photography and photobook making as a central part of my data collection. Many families are documenting their lives with readily available photo technology (Everpresent, 2016). These photos present a family with the opportunity to tell stories about their experiences. As I spent baking time with Toby, I purposely wanted to tell a story about the science in which Toby and I were engaged as she participated in our baking of challah, the traditional Jewish Sabbath bread. I sought connections between identity development theory, which proposes that we need to think of ourselves as a member of a community to practice within it (Wenger, 1998), and storytelling, which is a method within many cultures to help transmit a specific cultural history of identities (Aghasaleh, 2019; Boyd, 2009; Gottschall, 2012). I have examined my overlapping boundaries of family member and science educator. Within both of these identities is the value of distributing knowledge. This paper concludes with possibilities for broader distribution of science education techniques for family use.

My career (and professional identity) has concentrated on “continual science learning” (CSL), as I refer to it, more commonly called “informal science education” (ISE). The terms approximate the kind of science learning that can happen almost anywhere when we pay attention to learning about how the world works. I prefer the term “Continual Science Learning” because it conveys a value to learning outside of schooling that “informal” does not, and it implies the cumulative nature of learning to which Tal and Dierking referred (2014). In this instance, I explored a science learning opportunity with Toby in my kitchen as *place* because it is not nestled in a science center, museum, zoo, aquarium, afterschool program, park, or other programmatic or institutional setting. Cooking is an essential (and culturally imbedded) activity among most families, making this form of CSL a far older way of learning science than formal schooling or other science education institutions. For, learning how the world works so that we can meet our needs predates schools (and even humans), because survival depends on our ability to learn, adapt, and, in the case of social animals, share the learning (Jarvis, 2006; Wilson, 1975).

We are continuing to learn that survival today is not centered in our tribe or community (Common Worlds Research Collective, 2020). Transport, communi-

cation, and a global economy connect us around the earth. Science has helped us understand what, how, when, and where we need information about interactions and impact. More critically, STEM education provides a means to learn how to learn (Bronowski, 1978; Quigley et al., 2010; Ritz, 2007). For both personal and global needs then, it is essential for science educators to assist families to engage in the process of encouraging their children to think of themselves as “science people,” identifying as capable participants, increasingly responsible for their share of survival.

Research has shown us that there continue to be people who perceive STEM as difficult (García-Pérez et al., 2020). We also have evidence that there have been systemic biases against women and other groups to gain and control STEM knowledge (Delpit, 1995; AAUW, 2010). We in the science education field have an obligation to share our knowledge to support our global communities to not only survive, but also thrive in harmony with the earth that supports us (Ross et al., 2015). Science education research can gain insights into how we encourage interest in STEM among all earth’s people with whom we are interdependent. We science educators continue to seek ways to understand how both children and adults maintain curiosity in how the world works through asking questions, observing, gathering data, evaluating outcomes, and working together to solve problems (Ash et al., 2012; Lederman & Abell, 2014; Rogoff, 1990). We work towards supporting confidence in understanding the nature of science, its perspectives, its contexts, and its tentativeness (Fleer, 2009; Lederman et al., 2002). Those of us who concentrate on CSL pay attention to the non-curricular ways in which science learning happens. The investigation I am reporting here presents a case study of how I combine my personal and professional science educator identities. My interest is in sharing my insights to encourage other families to support their children to maintain the curiosity and problem-solving skills within their own cultures that are key to science learning and ultimately, survival for all of us.

This paper then, describes the background, processes, and outcomes in the use of a photobook created to document a cultural baking and science activity. As we move through the baking steps, I ask my granddaughter to do the measuring and mixing to develop competence. I ask her to consider what ingredients like sugar, yeast, and water contribute to our bread and how changing the amounts might change the bread. I see this participation and my questions as ways to enhance my young granddaughter’s science identity---to practice as an everyday scientist who can feel physically and mentally able to consider ways in which to manipulate, observe, consider, and discuss outcomes. I am supporting her emotionally by welcoming her happily into the process (Immordino-Yang & Damasio, 2007).

Documenting this baking science apprenticeship through photographs and captions as a photobook creates an artifact to which my granddaughter could return (Tomson and Holland, 2005). I experimented with this process earlier and found it useful (Katz, 2011). Recent research in Australia, employing photobooks with families after using exhibits from a science center outreach program, provides evidence that photobooks enhance recall, stimulate conversation, and aid in science identity development (Howitt & Rennie, 2021). With this granddaughter, I added a specific cultural component. I suggest that family photo storytelling may be one useful way in which to encourage families to purposefully tell their everyday science stories supporting their children to see the STEM in their own

culturally imbedded lives. The within family case study reported here follows in the tradition of Piaget, who examined his own children's cognitive development (Babakr et al., 2019) and Dana Vedder-Weiss (2017), who more recently studied her children's serendipitous science learning during home schooling. The three research questions I pose here are:

1. What is the relationship of my identity as grandmother to my identity as science educator/researcher?
2. How do I employ these dual roles in my purposeful effort to develop my granddaughter's "science person" identity?
3. How do the insights gained in this case study provide possibilities for other families?

Theoretical Background and Prior Evidence

Nature and Nurture

In considering how I make choices and act, blending my grandparent/science educator identities, I have drawn from theory in a number of fields that intersect. I first look at evolutionary biology. There is evidence that human families (however defined) provide the vital role of early learning about the world, as both protection and preparation for adulthood (Galinsky, 2010; Rogoff, 2003; Wilson, 1975). The discipline we call science, and more broadly, STEM, is an approach to learning about the world so as to protect and prepare us in our lives. Rutherford & Ahlgren, 1990; Bell et al., 2009). By starting with the theory of adaptation, we can gain insights into how we and our social interactions and institutions meet the life needs underlying our complex activities. According to basic evolutionary theory, genetic (inherited) and behavioral (how we live) components contribute to how we adapt and live to pass on our genes to the next generation (Darwin, 1859/1968). Evidence from our primate cousins suggests that we developed family learning patterns (even early identity through status) over millions of years as we assessed our performance among group members (De Waal, 2013). Evolutionary studies suggest that the survival of grandparents beyond their own reproductive years is part of "inclusive fitness," a term that describes how non-parental but related organisms cooperate for added fitness or survivability (Fisher 1973; Alvarez, 2000). Biological research has uncovered genetic evidence that our brains are protected from post reproductive decline (Schwarz et al., (2015). This would seem to indicate that our bodies are expected to function and presumably contribute beyond our own years of producing offspring. Recent reports from both the U.K. and the U.S. on the contributions of grandparents to their families support this biological theory (Brooks et al., 2009; Ferrie et al., 2016).

Human families have evolved a long period of childhood learning to provide for the complexity of what must be acquired to survive (Volk, 2011). In addition, Volk continues that this is recognized as play---a key element of CSL places (museums, science centers, aquaria, afterschool programs, and many activities in homes). Fenichel and Scheingruber (2010) write, "In the course of daily life, virtually everyone engages in informal science learning." (p. 1). They continue, "Everyday learning includes a range of experiences that may extend over a lifetime...

and may vary greatly across families, communities, and cultures” (p.3). Science learning within families is continuous (Gopnik et al., 1999.) We learn physical tasks of balance, walking, and hand manipulation. We learn how to obtain food, cook it, and eat it in flavors familiar to our family cultures. Food preparation involves measurement, materials science, and food safety. We celebrate events in our lives with culturally familiar rituals and music. Physical activities (including music and dance) require testing balance and movement.

There are many ways in which we have evolved to support learning how to survive in this world. There is research on mirror neurons that tells us that we have evolved to learn socially by being wired to mimic expressions and emotions around us starting from birth (Meltzoff & Marshall, 2015). Our early beliefs, attitudes, values, and motivations mimic those who care for us. Babies learn to smile from the happiness of their parents (Meltzoff & Marshall, 2015). We share emotions among our social group (Immordino-Yang & Damasio, 2007). Trust is an essential part of parenting/grandparenting. Trust in a teaching relationship is paramount. It is the basis of all teaching (Dillion & Avraamidou, 2020). I had played with Toby since birth. Baking and building were other forms of play where our processes yielded something for which she gained a useful product and recognition. I took photographs often. Photo documentation was a comfortable part of what we did together. She would ask at other times to look at the photos and she would tell me what she remembered from the images. We frequently read together. Her home and mine have a good selection of children’s books. Most of these books tell stories. Biologically, we have developed to absorb and copy our family cultures. Through experience, we participate in the work and play of our homes. We observe how our families spend their time, what they choose to own, how they talk, and what they talk about. We find (or are assigned) our roles and grow to know our family’s expectations. There are exceptions, but generally, our family’s stories become ours.

It follows that closely related adults, usually parents or grandparents, help their offspring safely survive by assisting them to make sense of the world they have come into and to develop useful skills consistent with family cultural identities--everyday science. Interestingly, there is more research on grandmothers than grandfathers. Perhaps it is because there is less paternal certainty for men, or perhaps because culturally, men have been harder to study as they can be less accessible when their work takes them away from the home. More often, grandmothers are available for both their knowledge and their caregiving. This follows a pattern that has been observed among some other long-lived mammals as well. Notably, grandmother orcas (killer whales), in the Pacific Northwest where I now reside, live years past reproductive age (and the males). They have been monitored leading their family pods to food sources when the customary source is scarce, directly affecting survival rates (Nattrass, et al., 2019). Evidence from research on mammalian grandmothers, including humans, suggests that my imperative to share my own learning within my family has strong biological roots running deeply as a survival strategy, even across species. Within my identity as a science education researcher, I believe that I have an obligation to construct creative ways to assist this first, powerful STEM learning opportunity among other families, honoring and respecting cultures in which they have grown.

Identity Development

Sociocultural theory tells us that the family is most often the source of how we come to understand ourselves as part of a group with a history, a way of doing things, a way of looking at life (Rogoff et al., 2018). Identity speaks to how we see ourselves and how others see us in social settings (Gee, 2001; Varelas, 2012). I wanted my granddaughter's identity to include "science person." That is, I wanted her to feel physically, emotionally, and mentally confident to observe, experiment, question, collect data, draw conclusions and discuss her ideas with others. We have seen that families begin the process of identity development from birth as their behaviors and communications tell us what is available to the young within their family cultures (Rowe & Casillas, 2010; Sha et al., 2016). Families set expectations that influence their children's school achievement (Thomas & Strunk, 2017). This is not to say that no other influences are possible, but it is to say that family is where we first learn "to be in the world," learning to learn and to interact with other people. I chose to explore from the position of a grandparent, as this is one of my primary present identities.

Continual Science Learning Within Families

What I call CSL is a large part of what happens in families. Children play and learn to test and evaluate within their home environments. Children draw conclusions. They alter strategies based on the evidence of their experiences. This happens whether or not anyone recognizes these as nascent science skills. I have approached most everyday learning within my family as science education opportunity. Not only children, but all of us need to learn as our world and we change throughout life--adaptation. This is at the root of why I prefer the term "continual science learning," to "informal science education--ISE." Families are the first, and often most powerful influence on our identities (Galinky, 2010; Sikder & Fleeer, 2014). They apprentice us in their own interests, values, and habits of mind (Sha et al., 2016). The science education professional community advocates for and acknowledges early exposure and family involvement to STEM (NSTA, 2009; NSTA, 2014). From these influences we craft our own identities as young people who may be free to choose, or may be limited, by how we have been nurtured. With the possibilities and potential for influence in mind, I invited my granddaughter to become a challah baking science apprentice.

Storytelling/Reading

From an evolutionary viewpoint, storytelling is an adaptation to gain attention "to explain things, from a child's or a country's pouty 'They started it' to why the world is as it is, according to myth or science" (Boyd, 2009, p.1). A story is a uniquely human art form that Boyd (2009) characterizes as "a kind of cognitive *play*, the set of activities designed to engage human *attention* through their appeal to our preference for inferentially rich and therefore *patterned* information." (p. 85). Others agree that storytelling is an ancient and enduring form of knowledge transmission and is perhaps what makes us human (Gottschall, 2012; Harari, 2014). Living in communities, our complex language abilities have given

rise to ubiquitous storytelling as a continuing form of this transmission (Boyd, 2009; Gottschall, 2012; Harari, 2015). Investigating the transmission of science as a way of knowing is to study how this aspect of human culture moves from one generation to the next. We are told and read stories about ourselves, other family members, or others in our communities. These often teach us acceptable behaviors and cultural ways of looking at the world (Bayer & Hettinger, 2019). Sfard and Prusack (2005) proposed that “we are the stories we tell” when they wrote of girls and math, as we form our identities of what we can and cannot do, linking storytelling specifically to math identity development. Other researchers have echoed the power of storytelling in science education, as did Avraamidou (2017) in her research in science teacher preparation. She explored the development of alternative narratives as a method to open new vistas to students whose former narratives did not include a science identity. I did the same with mothers who were leading the afterschool science enrichment programs I had developed (Katz, 2015). Stories help us to explain the past and envision a future. Considering this theoretical background, I set about to help create a narrative with Toby so that her story included a vision of herself as a comfortable, capable, early science participant. To make the story hers, I decided to create a photobook of one of our challah baking episodes. I knew that reading was an important early childhood activity and that a book about her would give Toby a sense of pride to further enhance her baker-science person identity. Earlier research had suggested that her storybook was a memory artifact (Thomson & Holland, 2005). She might choose to revisit the activity, to share the book with others, and to enjoy the attention of herself as the main character.

Photographic data for the story

Our eyes have evolved to sense visual images. Our brains interpret and store these images (Anderson & Contino, 2013). We have many visual neurons connected to multiple areas of the brain to accomplish this. Photography as data began in 1837 with Daguerre’s invention of a fixed image on paper. Photographs of human activity are data which can provide us visual stories of people in places, enriching verbal data, and used often in community studies (Banks, 2007; Mitchell, 2015). Photographs can be used to prompt memories for story recall (Harper, 2002). Photography has been used in educational research (Eschach, 2009; Liebenberg, 2018; Patrick, 2019; Prosser, 1998; Wang, 1999). Some teaching techniques specifically use photography (Park & Bell, 2005). Photography has worked well with young children (Hoisington, 2002; Keat et al., 2009). Julia Hirsch wrote specifically about family photographs that they are “a rhetorical device which our society uses to inspire and to coerce because these photographs look back at us and touch our values, our beliefs and our frailties.” (p.115). I chose photo storytelling because I was convinced of its power from both research and experience. With Toby, I could use photo elicitation (questioning derived from photo viewing), since she was accustomed to my frequent picture taking and questions. I also wanted to explore the photobook as storytelling artifact as a potential method for others. This paper then, considers the intersection of my own learning in evolutionary biology, theory and methods in continual science learning, identity development, and photographic data.

An October 2020 Worldcat search from 1950 (the beginning of the U.S. Na-

tional Science Foundation) to the present, for articles in peer-reviewed journals on “teaching science in schools” yielded 963, 350 articles. Searching for “grandparents teaching science in family settings”, only yielded 12,352 articles. Family data are harder to gather. Researchers from outside of the family must find ways to understand family dynamics in the episodes they are allowed observe. They have used family self-report surveys (Jungert & Koestner, 2013) and observations of family interactions in CSL settings (Szechter & Carey, 2009; McClain & Zimmerman, 2019). There are studies that include home visits (Zimmerman, 2012). Access is understandably limited. Alternatively, it is possible to study a family from within as a participant-observer (Vedder-Weiss, 2017). A participant-observer family member can yield data of a different sort, supported by trust within the relationships, and woven into the culture of family life. I chose to do this study from within, exploring my own identities and their impact on the science learning of one child in the close relationship of my grandparenting. Grandparenting has put me in this position to both observe and participate. I have an emotional and professional interest in this situation of teaching and learning. I had the advantage of access and professional knowledge and the inherent bias, which I discuss further on.

Theoretical consideration from evolutionary biology, CSL, and identity development through family cultural interactions, prepared me to approach Toby as a granddaughter needing and capable of learning early science through the activities necessary for life maintenance. The theories that support storytelling and the function of visual data provided me with methodological approaches to this research.

Context-Setting and Participants

My study with Toby took place at my home and hers. We baked *challah* at my home on Friday mornings for our Sabbath meal in the evening. We worked in my kitchen and our conversations took place in both homes and sometimes outside as we played or walked. Toby is the youngest of three siblings. I began taking data for this study when Toby was three and a half years old and continued until she was six. Her older brother was eleven and a half when this study began. Her older sister was eight and a half. Their mother (my daughter) has a Master’s Degree and my son-in-law is a physician. These children have many advantages and a rich cultural heritage in which they are also immersed. Toby’s parents and Toby herself readily consented to participate in Grandma’s work.

Baking offers opportunities for mentoring, tool using, experimenting, observing, predicting, testing and discussing outcomes (Zubrowski, 1981; FastTracKids, 2021). It has a natural payoff of something tasty to eat. For this *challah* baking book, a babysitter took snapshots. I made notes on paper and my cell phone over two and half years, which I transcribed into a project file. I apprenticed Toby not only in physical baking, but also through early science conversation (wondering out loud, considering alternatives, thinking of explanations). I gave her the opportunity to use the kitchen tools safely and added to her repertoire as she grew. We talked about how their shape and movement helped us. We followed a recipe and instructions. We considered alternatives. We observed. We tested. We also laughed, hugged, and tasted. She learned to take photos as well. We read the photobook together. She took it to her house and shared it with her parents and older

siblings. We talked about baking for food and baking as science. When I had a later opportunity to engage her in a furniture kit building processes, she readily agreed and I documented that, mindful that baking might be construed as a “girl” thing and that building-engineering would expose her to other STEM possibilities. I was studying my processes to engage her. By combining our activities with photographs, arranged, and captioned as science storytelling, my goal was to help her develop an image of herself as a welcome and competent partner to me, and generalizable participant in the STEM world.

I have worked with visual data for many years. I include visual data to offer an alternative or supplement to literary data. Photography and drawing have allowed me and others to work with children who cannot yet write (Katz, 2011; Dai, 2017), with groups of people without a common language (Cainey, Humphrey and Bowker, 2017) and with those guided to consider visual data in addition to textual resources (McClafferty & Rennie, 2017; Patrick, 2017; van der Veen, 2017; Wind, 2017). Visual data expands the way in which I can tell the tales of how people learn science outside of schooling. I decided upon the photobook artifact as a central part of my research with Toby for these reasons.

Toby’s house and ours are private houses in the Pacific Northwest of the United States less than a mile apart. The homes have many books and toys. Her parents have encouraged their children to be physically active as well as academically successful. They bike, skate, swim, ski, run, and hike. They have learned to maintain their equipment. They take music lessons. In addition to preschool for Toby and public grade schools for her siblings, the children attend a supplementary religious program, where they are learning Jewish history, customs, and Hebrew.

Toby is generally an exuberant, extroverted little girl. As the youngest of my daughter’s three children, she watches her siblings and often mimics them, trying out both her sister’s and brother’s skills and strategies for attention. She has play dates with other children of her parents’ friends and those friends she makes herself in preschool. While I have seen her tired and cranky, she is generally cheerful and offers to help out when the opportunity presents itself. She observes details and has a good vocabulary to describe her experiences.

As the auto ethnographer and therefore participant/researcher in this study, my preparation has been multi-faceted. To help establish trustworthiness, I include an overview of my own story to support my position and the authenticity of my work and approach (Guba & Lincoln, 1989). My parents were the children of immigrants. Neither spoke English when they started elementary school, nor were they able to study formally beyond high school because of the Great Depression in the U.S. Even so, they were grateful for Roosevelt’s social programs. Their government had been compassionate in their survival. They brought a sense of social responsibility into our home. Although we were not religious, I learned that the values by which we lived were imbedded in our cultural lives. Rabbi Hillel (a first century B.C.E. sage) wrote a succinct, often-quoted guide: “If I am not for myself, who will be for me?; If I am for myself only, what am I? If not now, when?” (Epstein, 1935). My parents, my brother, and I helped family and neighbors, as they helped us. We raised our voices for Civil Rights, Women’s Rights, and alternatives to war. Although my father did not have a higher education, he had an eager mind, interested in biology. As a butcher, he brought home lamb, chicken, and calf skulls and would ask me to notice their features and analogous parts. Sometimes,

he would ask me to observe or tell me how chicken bones articulated with one another, when they were already on a plate of food. My mother loved reading and writing and took me to the library often. I was the first person in my family to graduate from college. I had a limited vision of what my professional options were. My parents were eager for me to become a teacher, to them a stable and respectable woman's job. I taught in NYC and Washington, D.C. schools for three years. As I taught, I also absorbed the changes of the late 1960s. I was fascinated with the communications research being done with dolphins and chimpanzees. Opportunities were beginning to open up for women. I decided to return to school to take science courses. I was able to work with prairie dogs and bower birds among other projects that taught me science research methods and animal communications. I also learned much more about the academic world when I married a young college professor. He had chosen to teach in an inner city college with a majority Black student enrollment, supporting the changes brought by the civil rights movement. As my science education work evolved, I, too, felt compelled to seek ways to bring the afterschool program I developed to those who might not have had enrichment advantages. We have been fortunate to be able to live our values.

My afterschool science career came about serendipitously. My husband took his first sabbatical in Toronto, Canada. With our three young children, we repeatedly visited the Ontario Science Centre. I learned that there was a field of science teaching that would use my interests, skills, and desire to teach as social change. I came to interpret out-of-school science and "science for all" as one distribution of social power. I saw science as more approachable outside of schools, without tests and as an extension of playful exploration. Out-of-school science had been labelled Informal Science Education (ISE), a term which I grew to view as inadequate as I came to understand its importance. I initiated and oversaw the development of a local afterschool science program that was soon funded by the National Science Foundation to test its portability around the United States. It grew to a presence in 43 states and was contracted by the U.S. Department of Energy and the U.S. Air Force, among others, to provide programming to children/families in their locales. I worked with this program for 25 years. My own children often gave me feedback on activity ideas. As I began to seek answers to what the program was accomplishing, I returned to a nearby university to complete a doctorate in science education research. The program I developed and my subsequent projects have largely involved learning among families. For the program's internal reports, I queried the parents' choice(s) to enroll their children, what interested children and parents, and what their satisfaction was at different ages and topics. External evaluators tackled the children's learning. Among my publications as I studied research, I investigated my oldest grandson's understanding of science, using a photobook (Katz, 2011), and the identity shifts and impact on mothers who chose to lead the groups with us (Katz, 2015). I explored the decisions made by three classroom teachers to take on our afterschool work (Katz, 2016). I led a paper reporting the outcomes of an internship in the afterschool program by teacher candidates (Katz et al., 2013). Both in my dissertation and later research, I have employed visual data. Drawings and photographs work well in a non-academic setting where these data collection methods do not create the tension of testing and evaluation. I edited a book of examples of the use of drawing data in science education (Katz, 2017). I continue to seek out projects where an understanding of science can lead to em-

powerment. Close to home, I could study how my family opened up the science perspective to empower a girl--one of my granddaughters. My science education work has spanned four decades. I have designed, implemented, and done research on afterschool programming and university teacher preparation that included CSL (Katz, 2007, 2011, 2017). I have found that each of these settings has had elements of identity development through storytelling. For young children, books and reading not only expand the world of stories, but help to build the emotional bond as families pay attention, cuddle, and /or sit together to share selected stories

Method

My dual identities as grandmother and CSL educator are what brought me to this research. I wanted to understand more about how the advantages I had as a family member and the methods I had internalized as a professional were interacting in the practices I employed as a way of knowing to my grandchildren. This meant studying myself and my interactions with them. I chose auto-ethnography as a research method to consider my thinking as part of the family dynamic. I chose to focus on Toby for practical reasons. She was the youngest of the accessible grandchildren. As a female, she might have been subject to societal prejudices about female roles (AAUW, 2015). From my studies, I believed I could be influential in her resisting such pressures. Her siblings were school age and already influenced by several years of formal education, making study outcomes more difficult to separate from formal educational influences.

Dana Vetter-Weiss (2017) recently did thoughtful work using self-ethnography to study science education within her family as they engaged in serendipitous science engagement (SSE). She distinguishes between self-ethnography and auto-ethnography. In self-ethnography, she is researching the cultural context. In auto-ethnography, she says, and I concur, that the researcher is focused on the impact of the self. My study is the latter. I am telling my own story. I have approached our necessary family activities (cooking, prime among them) to apprentice my granddaughter in life skills, explicitly indicating the science in which we are engaged. There is no lesson planning, but there is a structure to the activity. I do modeling, but my granddaughter is free to partner in setting the pace, using the tools, and asking questions at her level of interest. She was young, not yet reading or writing, although an avid listener to books. Toby also likes to scroll through the photos on my cell phone and retell the activities they captured. By documenting her science activity and labeling it as such, I help to create stories that recognize her as a young scientist and welcome her into the community of practice that is everyday science. For these reasons, I chose auto-ethnography to record and consider how I used my education in in this grandparent-child relationship over two and a half years to gain insights into what I do and how Toby responds.

I collected data from June 2017 through early October 2020. I kept notes about my observations and conversations with Toby. I made these notes both on paper and on my phone's note taking app and then transferred these to a Word computer file and kept them chronologically. The photographic data was gathered from several sources. I asked Toby's frequent babysitter to document a challah baking session when I began this research. She used my small Panasonic snapshot camera.

Other photographs of Toby or the two of us were taken by family members who forwarded them to me. I also took many of the photographs over the succeeding two and half years myself with both the camera and my cell phone. They were filed electronically by date in a computer file dedicated to this research. I took several videos, which were also filed with the snapshots. My family is accustomed to my taking many photos as the “family historian.” Taking snapshots of activities is a frequent activity whenever I am present. It is not unusual for my children and grandchildren to say, “Take my picture,” when they are with me and want their activity recorded.

I began making photobooks in 2007 as a way to tell stories of our travels and events. I explored my oldest grandson’s understanding of what science meant to him as my first effort to use this medium for science education (Katz, 2011). This grandson is now 19 years old and recently asked me if I would like to go through the book pictures again and see what his notion of science is at this point in his life. We read through the book using Zoom technology and recorded the session. His continued interest in my work and his growth as a “science person” provide me with evidence that an explicit science focus from his youth has remained as part of his identity. This made me even more optimistic about the power of photobook storytelling as a longitudinal memory.

The first baking/science photo documentation with Toby was done June 2, 2017. I asked Toby’s babysitter to position herself facing us in the kitchen work area and to take photos as we prepared the challah dough together. I gave her no other instructions. When I viewed the photos, I selected 40 from the 134 images she took. I chose them with three criteria: 1) Storyline, as a visual reminder of her participation in the process; 2) Specific “science person” cues that would identify her as such; 3) Potential for captions and copy that would include questions that would continue to engage Toby in thinking about how things worked. I used these criteria to connect my purpose to the research on stories as identity builders. I wanted to potentially model how my choice of this family activity could be an opportunity to document CSL goals in family life. In our family culture, pinpointing the opportunities for science and mathematics are part of who I am as a grandmother and what I do within the family. For example, when we raise our glasses for a Sabbath toast, the children are encouraged to calculate the number of clinks, dependent on the number of guests at the table. The younger ones observe the older ones and this math game has passed along among the grandchildren now.

The book uses techniques I have learned about asking questions and conversing with young learners (e.g. Valle & Callanan, 2006). When the photobook was produced and first arrived (July 2017) we read it together and I made notes about her comments. I had ordered two copies and left one in our living room. I wanted her to see our pride in her participation and to see if she revisited it. She was eager to take her copy home and show her family a book all about her. The cover of the book (with her name blocked out) is shown below in Figure 1.



Figure 1. Photobook Cover

This was our first reading and conversation.

Grandma: Do you like the book?

Toby: Yeah, I like the pictures of me.

Grandma: What do the pictures tell us?

Toby: That we were baking and having fun.

Grandma: So, you are a baker?

Toby: Yeah.

Grandma: Are you a scientist?

Toby: Yeah.

Grandma: What is a scientist?

Toby: Ummm. I don't know.

This was interesting. I realized that at almost 4, she had not been exposed enough to the connection between her own science activity and what a working scientist did, even though she had accepted the term “scientist.” She had been entranced with episodes of *The Magic School Bus*, (on which I had been an adviser), and she certainly had absorbed Ms. Frizzle’s mantra and mine, to enthusiastically “Take chances!” and “Make Mistakes!” but in this first finding, I learned that she did not yet have the concept of a working scientist.

Analysis

Since the baking/science photobook with Toby was a key piece of this research,

I planned for input from other science education professionals in considering my own potential bias. I asked two colleagues to review the photobook (separately) and score their thoughts on the match of the photos to the Informal Science Strands described by Bell et al, in 2009 in the U.S. National Research Council's publication, *Learning Science in Informal Environments*. Having designed the research and book, I did not score the picture inclusion myself because I had "spoken" in my initial choices. I provided the photobook and a table asking each colleague to check the presence of these strands for each photo. I left the room and there were no further conversations about the photos or scoring. My colleagues scored their observations of my photo selection by marking the presence or absence of any strand in each photo. Table 1 shows the NRC Strands (Bell et al, 2009) and in the rows below, the number of photographs (from the 40 I chose) that each of the two raters viewed as evidence for each strand.

Table 1. Picture inclusion analyzed by Informal Science Education Strands

There was clear agreement that my photo selection for Strands 1, 3 and 5 were consistent with the goals. As I discussed these ratings with my colleagues, the first rater expressed that Toby was surely participating, but that she did not see evidence that Toby was generating, understanding, and using models in the snapshots---Strand 2. The second rater equated Strand 2 and 5 more closely. Both did not see much or any evidence of reflection on science as a way of knowing and I came to agree with this as I talked to Toby (Strand 4). I found the responses on Strand 6 about identity especially puzzling when I first looked at this data. I came to understand that giving Toby words and pictures to support her "science person" identity was only a beginning, which she herself confirmed as we talked months later. She did volunteer that she recognized herself as part of a generational learning pattern. I had not expected that:

January 2018:

Grandma: How do you feel? Do you like science?

Toby: Yeah.

Grandma: Why do you like it?

Toby: Because it's fun.

Grandma: Do you have any idea what makes it fun?

Toby: Baking. The baking and the measuring makes it fun.

Grandma: So, okay, are you, are you a scientist?

Toby: Ah uh. Not quite yet, but a little bit. I am learning to be a scientist. But, if you teach me lots of science, I'll be able to make that science and

teach it to my kids when I grow up.


Grandma: Wow. I didn't think about that. You think you'll do the same thing? You'll teach your kids? Hmm. And then when they grow up....

Toby: They will teach their kids.



The photobook contains both visual and literary data from which I have provided samples below. For consistency, I have used the NRC Informal Science Education strands for the photo/caption analysis (Bell et al., 2009). In Table 2 below, I have analyzed sample images from the photobook with their accompanying captions. The left column has the captioned photo samples. In right column, I analyze the support I have learned to provide as a science educator over many years. I have labeled it ESS (Explicit Science Support). This acronym is also a cultural and somewhat humorous reference. "Ess" in Yiddish, derived from German, is an imperative to eat. Jewish mothers are often pictured as encouraging their children to eat by saying, "Ess, ess mein kind" (eat, eat, my child). In this sense, we encourage our children to be nourished and to thrive. Applied here, I am supporting my granddaughter's ability to thrive by making science part of her intellectual nourishment.

Because these data follow the NRC strands, they are not chronological to the baking sequence

Table 2. Sample photographic and caption data from the photobook.

1: Experience excitement, interest and motivation to learn about phenomena in the natural and physical world.		
image	caption/copy	explicit science support
	<p>Wow! In a few minutes, Toby sees foam at the top of the mixture The yeast is good What is the yeast doing? What will it do in the bread mixture? Let's see...</p>	<p>Selection of kitchen science experience that includes drama, participation, and learning about phenomena within the Jewish cultural framework of preparation for Shabbat.</p>
2: Come to generate, understand, remember and use concepts, explanations, arguments, models and facts related to science.		

Grandma says I am a little scientist

	<p>How does the dough feel? We add more flour until it is not very sticky.</p> <p>Making bread is a little different each time because the amount of flour depends on the humidity (wetness) in the air. We need to experiment and adjust the amount of flour.</p>	<p>Introduction to baking variables. Multi-sensory opportunity with Toby's participation and input into outcome determination (understanding, explaining conceptual development).</p>
<p>3: Manipulate, test, explore, predict, question, observe and make sense of the natural and physical world.</p>		
	<p>Grandma has a jar of yeast. What does the yeast do in a mixture of water, flour, and sugar?</p>	<p>Use kitchen science opportunity to prepare a food that brings science and our culture together in sense-making about the processes that require tool use, prediction, testing, questioning and observation of results.</p>
<p>4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.</p>		
	<p>We are baking in our kitchen to make food. The kitchen is also like a scientist's laboratory--we are doing baking chemistry!</p>	<p>Science is a way of developing and using information. Involve Toby in all of it.</p> <p>Age appropriate limits: No institutions here. Little metacognition.</p>
<p>5: Participate in scientific activities and learning practices with others, using scientific language and tools.</p>		

	<p>We measure the warm water. Grandma added enough water to have almost 1 ½ cups. Toby tells Grandma that we need just a little more to be just right on the measuring cup line. Grandma adds the warm water until Toby says, “It’s just right.”</p>	<p>Bake challah and label it science with me and at other times with others. Learn to use measuring and mixing tools safely and appropriately as part of a caring apprenticeship.</p>
<p>6: Think about themselves as science learners and develop an identity as someone who knows about, uses and sometimes contributes to science.”</p>		
	<p>Toby is practicing science She is a kitchen chemist. She is measuring, mixing, observing, and figuring things out</p> <p>Toby likes to be a baker and a little scientist with Grandma It is fun!</p>	<p>Be explicit about the partnership in learning science and label it as such.</p> <p>Reinforce emotional component of trust, learning, and identity development.</p>

I had tried to tie science and baking together. What I learned as we continued was that I had not considered that my young granddaughter was directly equating baking and science and had not yet developed a more generalized concept of what it was to be a scientist as an adult. I had made assumptions and had to reconsider these. Not much later, at her house, Toby’s brother proudly wanted to show me that Toby was learning about science from me. Below is their brief exchange. March, 2018:

Brother: Are you a scientist, Toby?

Grandma says I am a little scientist

Toby: Yeah.

Brother: Why do you think that you are a scientist?

Toby: Because Grandma says so. She wrote a book about me.

This exchange confirmed that Toby trusted my efforts and judgement and that the book was influential. However, as I interpreted this exchange, I wanted to adapt to broadening Toby's opportunities to expand her everyday science experiences beyond the kitchen for her science person identity. I invited her to play with games and puzzles that employed manipulative and reasoning skills. She liked the simple game of pick-up sticks. It requires strategy and small muscle control. I asked her to assist in building a gate-leg table from a furniture kit. I photo documented this process and made another photobook. In that photobook, I talked about Toby's construction and engineering skills. In 2020, reviewing these data, I again wanted to query her, especially about her conception of science. She had said, "if you teach me lots of science, I'll be able to make that science and...." (2017). Was science still the same to her as making/baking bread or had she developed a generalized approach to learning about the world? Along with my activities, she had preschool experience by this time.

October 2020

I hoped to gain additional insights through another conversation with Toby shortly after her sixth birthday. I was aware that she liked to please me and so I asked my husband if he would visit her at her house and talk with her once again about her views of science and her identity. This was recorded and I transcribed it.

Grandfather (G): Can you tell me...what does the word science mean to you now?

Toby: Practice.

G: What?

Toby: I said, practice and possibilities and things that people haven't discovered before.

G: What kinds of things?

Toby: Probably, like, the first person that discovered crystals.

G: Crystals Is that a scientist?

Toby: Probably, or, like, uh, things that you do, like you do it and you memorize it so you know how to do it.

G: What do you memorize?

Toby: I memorize the book with pictures in it.

G: Yeah, you did. So, where do you learn about science?

Toby: At Grandma's house[Laughs].

G: At Grandma's house? Is that the only place you learn science?

Toby: No, I learn at home. I bake with my mom, of course.

G: Well, who can do science?

Toby: Grandma.

G: Is that the only person who can do science? Grandma?

Toby: No. You and mom and probably Dad. And probably my brother and sister and probably some of our neighbors.

G: Well, can you do science?

Toby: A-uh. Well, I can do science a little bit.

G: What kinds of things can you do?

Toby: Baking.....and learning.....and discovering.....

G: What kinds of things do you discover? Have you discovered something?

Toby: Laughs.

G: What kinds of things do you discover?

Toby: I discovered a bottle, a glass bottle (moves hands in bottle shape) that was this tall. It was sea glass. It was ...thrown back in the ocean.

G: So what is sea glass?

Toby: It's a kind of glass. It's from the sea. Someone has dropped it into the sea.

G: What does the sea do---anything?

Toby: When it got spiked in, it makes it, um, it makes it not as sharp. The edges not as sharp, like they would be.

G: How does the sea do that?

Toby: I don't know

G: What do you think?

Toby: It scrapes on the sand on the bottom of the ground and it's full of crabs with their claws.

G: Crabs, oh.

Toby: And they step on the bottom of the ground.

Vic: That's an idea.

Toby: And they go splash and splash and the hard waves go "wheek, wheek."

G: Anyway, so what do you like about science?

Toby: Oh, it's fun. And it's learning and discovery.

G: You like to discover things?

Toby: (Nods yes).

G: Is there anything you don't like about science?

Toby: (Nods "no"). Science is fun.

At six years old, Toby still considers baking a key science experience with me. We continued to make challah frequently, so it is a well repeated memory. She indicates that others who bake are also doing science. Toby has developed a view of science that includes general learning and discovery. She uses an example she provides outside our relationship and experiences together. She had found sea glass along the beach. When probed, she readily says that she does not know how sea glass is smoothed, but she is also willing to put forth a reasoned explanation. She has confidence with both answers. There was no shame in not knowing. There was a willingness to draw from her situational observations and venture a proposal. Toby's identity as a participant includes a wider swath of activities and in this way, I see her as a young girl confident in her everyday science participation.

Findings

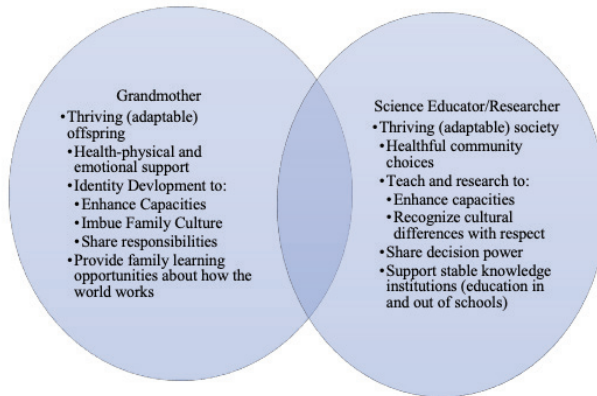
My first research question asks how my two identities of grandmother and science educator overlap. My biological instincts to nurture my granddaughter were evident in the time, attention, and affection I gave her with a welcome into a "science person" identity through an apprenticeship in challah baking within our culture and early science support that I had learned through my own education. What did I do as a trained science educator in this featured challah baking activity? I referred to years of reading science education research and viewed the data through the

lens of the National Academy of Sciences report on Learning in Informal Environments, including the home (Bell et al., 2009). I asked Toby to notice things (example: what happens to yeast when mixed with water and sugar?). I apprenticed her in the use of tools (example: measuring spoons and cups, mixer). I asked her to consider alternatives (example: changing amounts of sugar or flour). I asked her to describe what she was observing (example: stickiness of dough). I asked her to solve problems (example: What can we do if the dough is too sticky?). I welcomed her into the community of practice of everyday science by respecting her answers to questions and referring to her as a young scientist. I offered her messy fun in the baking process and excitement with the finished bread. I connected science learning through a trusted relationship and warmth. In these ways, Toby was exposed to all six strands described by the NRC publication during the challah baking activity that I documented. Although we did talk about science as testing and organizing our tasks, I did not converse with Toby about her own metacognition or science institutions. These were not age appropriate concepts to me. I also concluded that professional science work was a concept that would come along as her life experience broadened. Toby sees me as her grandmother and science person in her partnership with me. She accepted my designation of her as a young science person. The photobook was an artifact that told Toby's story as a "baker and scientist." It was available for voluntary reading. I cannot report all instances of "reading" (or being read to) because one copy was at her home and I did not have access to information on all readings (parent, sibling, babysitters), or her own picture viewing. At my home, she picked up the book to ask for a reading, or flipped through it more frequently when it was first printed and less so as time went on, but it was referred to at times throughout the two and a half years of the study.

Toby was clear that at 3½, she knew she was able to bake. But when I probed for her understanding of whether she was a scientist, she had said, "I am learning.." This gave me the opportunity to think about how the science in our activities could be made more explicit. I would say, "This is science because we are testing the yeast (proofing)," or "this is science because we are considering the variable of humidity--the moisture in the air."

My analysis is an example of the balance of nature/nurture arguments. Evolutionary biologists, notably, Richard Dawkins, have proposed that life continues through "selfish genes" that control their own self-perpetuation by directing the body that hosts them (Dawkins, 1976). Considering this theory, I should be compelled to care about my granddaughter's optimal chances for survival and science participation as a mechanism to do that. As well, the work of Etienne Wenger (1998) and Barbara Rogoff (2003) speak to how we nurture our need to learn (and survive) during our lives by participating in communities of practice that afford (or channel) our opportunities for learning. As a science educator and researcher, these theories have guided me. I have learned to provide opportunities for "science for all" within the social context that is the fiber of society supporting all individuals. My education then, prepared me to see science as a useful thinking tool. My family culture helped me to choose further education and a career that could enhance the lives of others in our mutual home on earth and for personal satisfaction. This Venn diagram in Figure 2 visualizes the overlap of dual roles:

Figure 2. The Overlap of Grandmother and Science Educator Roles



My second research question asks how I employ these dual roles. My data provide evidence that my grandparent relationship---in which I have helped to nurture this grandchild, and my career---thinking and acting so that other children/families can use the benefit of science education research, are intertwined. Both relationships share the limiting (and enabling) factors of our planet and its resources. For myself, my family behaviors (enacted in my cultural context) and my professional behaviors (an education over decades) support each other. Biology theories have informed me that to survive as social animals, we must meet individual needs and group needs. Science education is to me an essential enterprise then, on both a personal and professional level. In each case, I have been engaged in supporting the activities and the welcome to become “science people.”

I posed my third question to ask how this piece of research might be not only relevant, but enacted within other families. A Pew Research study posted in April 2021 reported that 97% of the U.S. population uses a cell phone (Mobile Fact Sheet, 2021). Globally, two-thirds of the world’s population have unique mobile phones (Digital Around the World, 2021). Photographs are freely being shared on social media platforms such as Facebook, Instagram, and share sites, such as Cluster.com or Shutterfly.com. Utilizing this existing photo sharing trend, I have given some thought as to how it might be possible to inspire families to support their children as STEM participants, through photo storytelling, picturing themselves as continual science learners. Not all families have access to photobook technology or want to budget for photobook purchases. There are other options. For example, bloomlibrary.org allows anyone with a computer and printer to produce their own books. Perhaps, my enjoyment of physical books is a 20th century relic to young families today. Perhaps they will derive benefits from the storytelling experience in digital form alone, reliving and talking among themselves simply by looking at their snapshots with science in mind. It is the professional challenge of science educators to be activists in suggesting ways to put science in mind through prompts and encouragement. I think of cereal boxes, milk cartons, and other places where I have seen educational games featured. Where are people already gathering in their communities to share their stories? What partnerships might be created with CSL

institutions for website space or signage? These are certainly topics for further research, as is further family photography and the science identity storytelling process.

Limitations

I cannot claim that my influence has been the only source of my young granddaughter's comfort and eagerness to engage in science. Her parents, her siblings, and their way of living provide her with many ways in which to learn about the world and her agency in it. There is also the process of normal maturation and with it, changes in understanding. In this case study, there could not be a control to test whether Toby would express her understanding and interest with or without my apprenticeship. This is an advantaged situation in which my professional life and personal life coincided to provide my granddaughter with support for early science identity development. It is a study that is limited, as all case studies are, to one example, with the expectation that families have basic needs in common, and that the findings in this study may be replicable.

Conclusion: Summary and Active Advocacy (implications)

By focusing on myself, I was able to examine how I apprenticed Toby. I gave her attention. I used our existing emotional bond and the trust that she had with me to actively engage her in baking challah as a cultural activity that could be approached with its science content. I indicated how we could do baking science together and explicitly, how that made her a young scientist as my partner. I watched her mirror my enjoyment of science and the techniques I used. I documented her participation to tell the story of her experience, reading and repeating the story, and I listened as she adopted it as hers. I adapted to her readiness, praising her growth as she took on measuring and mixing by herself. She declared she was a young scientist because I had addressed her that way, clear evidence that I had some impact on her identity development.

Basic biological theories had predicted that I would want to pass on my useful survival skills and part of that was my strong emotional interest in doing so. I employed recommended science education techniques. When I looked at my purposes both as a grandmother and a science educator, they were similar and differed by scale---personal and societal. I recognize that learning is cumulative and occurs constantly (Dierking & Tal, 2014). My activity with Toby was clearly not a school requirement. It was not an exhibit, demo, or museum class. It was not serendipitous learning that happened as a child played (Vetter-Weiss, 2017). It was a science education opportunity that presented itself to me in our daily living. Such opportunities are recognized in professional discussions of science opportunities for parents/families (NSTA, 2009, 2014). This research is an insider's view of what can happen in a family setting, taking advantage of existing activities imbedded in a family's culture and explicit conversation about science. Reading and photography are widespread pastimes in many homes and I brought them together in my efforts. In this case, my granddaughter is growing up as a welcome member of the everyday STEM community as part her identity. Most families do not have

professional science educators. However they do have the same biological drives and concerns that I have about continuity and success of their children. They talk. They take photos and they relive their big and small adventures within their cultures.

The value of this case study is that it afforded a close and prolonged look in one setting. From this vantage point, it is possible to consider what is unique and what is worth investigating among a larger number of cases. I have provided evidence that my granddaughter is developing an everyday science identity partly through her apprenticeship with me in our family's cultural activities and rhythms. The processes I used to encourage science identity building with Toby were: 1) trusting apprenticeship 2) explicit science identity building 3) photo documentation 4) repeated storytelling, aided by photo elicitation. That she has had these advantages with a science education researcher grandparent presents me with a challenge in my professional life. Storytelling around family necessities contains science involvement in every culture. How can I link photography, in which many families are already engaged, to familiar and comfortable cultural activities that are science rich and are already part of their identities?

The photobook component has the advantage of being an artifact for revisiting a particular story. But the storytelling process is likely valuable without the expense. Further research within more and varied families is needed to compare my experience. I performed this research as a grandparent. Would parents and other family members take the time to document their stories through a science education lens? What support do non-science educators need to prompt the telling of stories about everyday science learning as they go about their lives? I see the challenge as two-fold. The first is an awareness campaign to highlight that families are already engaged in everyday science. The second is the process of science identity photo storytelling as an activity.

Perhaps by providing inspiration and guidance in photo documentation, photo elicitation and reading about the science already in their homes, this research can be turned to practice where the roots of attitude and interest develop---in the home. While it is more difficult to access and negotiate the home setting, I want to make a greater effort. In the U.S. there are many experts in marketing products. We see advertisements on every surface (buses, billboards, t-shirts, and social media). I suggest here that utilizing an activity (taking family photos of science activity) and telling ourselves identity stories is something that families are already engaged in, and with marketing, could be a way to honor and encourage science recognition within differing family cultures. At what age might children create their own auto-ethnographies of themselves as science participants? Much of this further research is dependent on engaging families from varied cultures. Forming collaborations with marketing entities that have co-interests in reaching families is a first step. Perhaps breakfast cereal producers, who aim at family markets and some of whom print games and facts on their packaging, would be a first possibility. Let us literally think outside the box in our need to take a more active approach to our knowledge sharing for all of our sakes. I invite conversation and action among my colleagues here and in other places around the globe.

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Engaging the Urban Classroom with the Natural World



Lessons Learned During a Pandemic

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Abstract

In this paper, the authors discuss an environmental education learning framework which was developed for an experiential course (an “[Un]Class”). Lessons learned are shared from teaching the course in an unintended blended in-person/online format as a result of the COVID-19 pandemic which occurred in Spring 2020. Impressions were developed from classroom observations along with an analysis of course assignments and a follow up focus group interview with students. Our continued work explores whether or not an urban university-level course, such as this [Un]Class, which brings preservice teacher candidates and biology majors out into nature in an experiential manner, impacts their likelihood to include such activities into their future (formal or informal) science instruction and more fully engage their own students in urban environmental learningscapes.

Key words: Science communication; field station; experiential learning; place based education; environmental education; STEM.

Background

In universities without formal environmental education (EE) classes or programs, exposing teacher candidates to natural settings for their required coursework can often be overlooked and challenging. Based on existing research, we can document that K-12 students from urban school districts are less likely to be exposed to nature and field-based experiences, thus we believe better preparing future teachers and interpreters to share their nature and environmental knowledge and skills can help bridge this opportunity gap (Heimlich, et al., 2017; Hughes, et al., 2019; Kuo, et al., 2018; McKeown-Ice, 2000). For the purposes of this paper, ‘urban’ will be defined as an area or school district with both socioeconomic differences

and “place differences” or areas with less access to land available for outdoor learning experiences (Parker et al., 2018). While this study takes place in an urban school district, ample opportunities for high quality park systems do exist regionally but access is not always easily obtainable for individuals in lower socioeconomic brackets. That said, in our study, there was an emphasis on utilizing local open spaces such as school yards and neighborhoods.

There have been numerous studies that have demonstrated that engagement with the outdoors not only enhances student learning but impacts teacher confidence and efficacy in using those settings for their own science instruction (Carrier, 2009; Lewis & James, 1995; Trauth-Nare, 2015). That said, preservice science teachers often lack the confidence to teach in outdoor settings, indicate discomfort with those settings, and have little understanding of the environment and environmental science (Barrable & Lakin, 2019; Bodzin, et al., 2010; Hug, 2010; Yavetz, et al., 2014). In order to move beyond such barriers, intentional inclusion of environmental education methods and skills (e.g., field trips, community service projects, and participation in outdoor science) should be incorporated into the coursework that prepares preservice teachers for student teaching and beyond (Tal & Morag, 2009; van Dijk-Wesselius, et al., 2020). “Through hands-on immersion, prospective teachers can feel and be motivated by the energy and enthusiasm children have for the natural world” (p. 9, Powers, 2004). However, it is not enough to simply have resources, methods, and skills specific to environmental education, they need to be integrated into preservice teacher preparation programs (McDonald & Dominquez, 2010).

In addition, research shows that boys and girls from marginalized and historically disadvantaged groups— such as Black, Indigenous, and People of Color (BIPOC) and students in poverty—are less likely to have access to and to pursue advanced coursework in math and science (Babco, 2003; Cole & Espinoza, 2008; Crisp, et al., 2009; Gandara, 2001; NRC, 2005; Tsui, 2007). This lack of access makes it more difficult for them to enter and be successful in Science, Technology, Engineering and Mathematics (STEM) majors and careers (this includes those with a focus on the environment). Research also shows that we need all voices at the table (racial, social, cultural, economic, age, gender, orientation, education level, geographic, religious, etc.) to help increase workplace productivity and idea generation (Lambert, 2016; Saxena, 2014), two crucial factors that help the human race address complicated and pressing environmental issues like climate change, plastic pollution, and worldwide species extinctions. However, there is also ample research to show that BIPOC and women are often left out or left behind in STEM fields, effectively limiting the diversity of voices that will be invited to even sit at the table (Bell et al., 2018). It’s a frustrating conundrum. Because beyond identifying the barriers to inclusivity, the real question for us remains: how can we help inspire students to not only learn to tolerate being out in nature, but to love nature enough to pursue it as a major in college, find a job in the field sciences or science education (often very competitive and low paying), become an expert in their field so they can sit at the proverbial problem-solving table, and be an educator, role-model, and mentor for all of the scientists and naturalists following behind them?

Although students do not take their first discipline-specific class until their freshman or sophomore years in college, the reality is that many students decide

on a major much earlier in life. A stated interest in STEM by eighth grade is more of an indicator of pursuing a STEM degree than math or science test scores (Dabney et al., 2011; Tai et al., 2006). Additionally, if students are not excited or informed about STEM disciplines while in middle school, they will make class/activity choices that may preclude them from a future in a STEM field (BGCA, 2014). Further, engagement of BIPOC community members in environmental education programs is essential (Lewis & James, 1995). Carter and Simmons (2010) stated that “environmental education begins close to home” (p. 12) and that ultimately, “the goal of environmental education is a democratic society in which environmentally literate citizens actively participate” (p.12). Furthermore, they state that creating specific teacher preparation programs that encourage environmental literacy has been a challenge.

This is why we felt it was important to provide EE experiences and engagement with the outdoors for our middle level preservice teacher candidates who have been trained in an urban school setting and who have indicated a desire to continue working in such educational environments. However, during the midst of teaching a semester-long EE course, steeped with experiential learning opportunities and outdoor experiences, there was the COVID-19 pandemic during Spring 2020. As a result, the remainder of the course was taught online. We wondered how an online experience was going to impact middle level preservice teachers and their relationship with nature or outdoor education and how might they incorporate EE into their future work with urban learners.

Participants

The course participants were 10 (3 male, 7 female) middle level (Grades 4 - 9) preservice teacher candidates, primarily in the Junior or Senior year of their licensure program, which consists of required coursework in two content areas (science, mathematics, language arts, or social studies) in addition to pedagogy coursework. All of the participating students were preparing to be licensed in science and required courses for such students include biology, chemistry, physics, geology, astronomy, and environmental science. There were other undergraduate students enrolled in the course, majoring in biology, as well as two graduate students, majoring in education and history. However, the focus in this paper is on the middle level teacher candidates (n=10).

Description of the Course

This study took place at a large public, urban, university in the Midwest USA where a novel course offering was implemented using established programs, facilities, and centers. Specifically, the university’s resources included an experiential learning center, an urban STEM center, and a locally accessible off-campus field station located within a nature preserve. The framework for this type of course is called an “[Un]Class”. By their design and nature, [Un]Classes are cross-departmental both in instructor and student make-up, interdisciplinary, and allow for small class sizes and active student involvement on topics that would not be normally found in the university’s course catalog. In addition, students play a large

role in how the course is structured and unfolds.

The course focused on activities from the field of environmental education and was designed to help preservice science teacher candidates build connections from nature to their classroom (whether formal or informal). Course participants were able to learn about and become certified in pre-existing nature-based curriculum like Project WILD (Council for Environmental Education, 2014), Growing Up WILD (Council for Environmental Education, 2016), Aquatic WILD (Council for Environmental Education, 2005), Project WET (Project WET Foundation, 2011), and Wonders of Wetlands (Kesselhelm et al., 1995). There was also a focus on how to deliver impactful STEM content to various audiences (i.e. children and adults in both formal and informal environments), including Problem Based Learning (PBL), and determine the best way to assess these types of interactions. The class met at the off-campus field station and included activities within the nature preserve as well as trips to other park systems, including a national park, and local agencies (i.e. the natural history museum). Local field trip experiences with K-12 school learners from a partner school district were also incorporated into the course. Again, this particular school district is designated as ‘urban’ because it is associated with a mid-sized city, with student demographics listed as 46.5 % Black, 32% white, 8.4% Asian/Pacific Islander, 8% multi-race, 4.5% Latino, and 0.6% other.

The purpose of this [UnClass, titled “All the World’s a Classroom”] was to bring together students from disparate majors (in this case it was open to all majors but cross-listed in Curricular and Instructional Studies and Biology) and to expose them to science communication, teaching, and learning in non-traditional, informal settings (local parks and museums). We provided them with a variety of resources and experiences that would increase their comfort in these settings in conveying complex STEM concepts to their future students or patrons in engaging and innovative ways.

The overarching goal of the class was to increase students’ knowledge of environmental education through a mix of literature review, free nature exploration, hands-on experiential learning, assignments, and place-based field trips (see Buxton & Provenzo, 2012), expert guest instructors, and earned certifications. We focused on how to deliver impactful STEM content to various audiences (K-12; general public) and determine the best way to assess these types of interactions. Due to the circumstances surrounding a global pandemic, the experiential nature of the course shifted mid-semester (around week 10 of 16) and the experiences were seen through a digital lens since students had to complete assignments in a virtual online learning space.

The class met for an extended block of time once per week (2.5 hours). Several different initiatives were utilized in this course in order to achieve the spirit of this experiential, student-driven course trajectory while maintaining some level of oversight on learning objectives. Specifically these initiatives including nature hikes (see Figure 1); semester long nature journals (Campbell & Fulton, 2014); participatory activities through EE curriculum; directed readings on environmental education and informal science pedagogical theory; required responses to articles and videos (i.e. “Media Responses”); peer teaching through a natural history hand-out and class presentation (i.e. “Research Project”); self-directed EE curriculum assignments at home; a community based action-focused initiative (i.e. “Upstand-

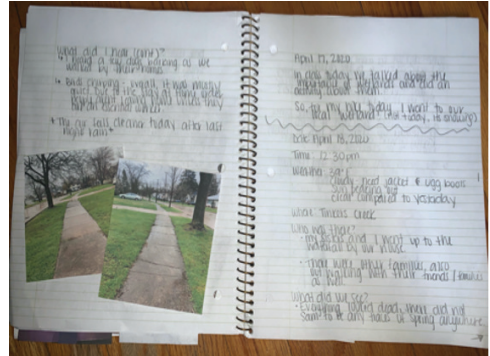
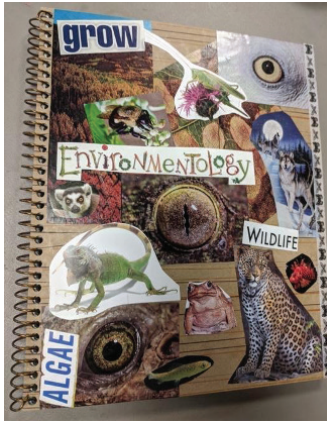
er Project”) and final team projects (i.e. “Curriculum Kits”) based on appropriate state and federal learning standards. Other features of the course included field trips to various informal science organizations (museums, parks, and camps), guest experts, and certification in several nationally recognized EE curricula.

Figure 1 *Nature Hikes*



Specific activities were chosen to highlight the important connection between humans and environment - this is a key factor in developing a personal and impactful relationship with the land (Leopold, 1949). These included weekly hikes (guided or in small groups); the creation of personal nature journal entries (through an art project); the required usage of those journals through field entries (see Figure 2); and topic specific EE activities (examples include: ‘Reading the Landscape’ - Leopold Education Project (Aldo Leopold Foundation, 2016); ‘Incredible Journey’ - Project Wet (Project WET Foundation, 2011); ‘Wetland Metaphors’ - Wonders of Wetlands (Kesselhelm et al., 1995); ‘Bird Beak Buffet’ - Growing up WILD (Council for Environmental Education, 2016); Biomimicry Exploration - Field Station Developed; etc.)

Figure 2 Examples of Students' Nature Journals



Other assignments were specifically designed to increase knowledge about the field of environmental education. There were assigned readings and associated Media Responses where the students were asked to reflect on their interpretation of the literature by elaborating on the leading statements “The Text/Author Says” and “I Say” on at least three passages from each article and write summary statements. Other activities focused on knowledge development included the participation in EE example activities, visiting guest experts, field trips to meet with informal science professionals, and field trips to respected institutions such as a local natural history museum and an overnight camp. Furthermore, students could elect to get certified in and therefore receive guides for existing EE curricula - Project WILD (Council for Environmental Education, 2014), Growing Up WILD (Council for Environmental Education, 2016), Aquatic WILD (Council for Environmental Education, 2005), and Wonders of Wetlands (Kesselhelm et al., 1995).

Many of the assignments were chosen based on the allowance of substantial student choice or the ability to go in many different directions. To this end, although we had rubrics for the Research Projects, Upstander Projects and Curriculum Kits, students were allowed to choose their own topics and thus they showed a variety of interests and perspectives.

As previously mentioned, mid-semester the class had to transition to at-home virtual learning, which initially for an “experiential, hands-on” class felt a bit like a death knell. The students were asked to shift to this new pandemic-inspired format by first joining class for a virtual weekly check-in which was truncated in length from a normal class. This gave us all an opportunity to briefly go over weekly assignments as well as to answer any questions, and maintain some connection with students other than just through email or the university-sponsored online learning platform. They also had to record their Research Project presentation to share with the class and the development of the final project (Curriculum Kits) became an on-line activity, as opposed to the creation of an actual physical activity box. Students were expected to continue to explore nature on their own time, keep up with the field journals, and complete required readings and assignments during the remainder of the scheduled class time or throughout the week.

The Curriculum Kits were redesigned to be digital, using Google Sites, to include necessary background information, connections to state standards, clear descriptions of the proposed activities, assessments, supply list, required materials, supplementary resources, books, plenty of interesting visuals, etc. Students mostly worked in pairs and were given feedback before final submission. The topics included: Tree Families, Painting with Soil, Polluted Display Jars, Think Like an Early Ohioan!, Plant Cells and Their Functions, Introduction to Ornithology, Animal Tracking, and Food Chains and Food Webs. The intent was to have the kits be complete enough so that teachers and families could use the content and materials in a digital format. The kits were made available through a university sponsored press release and a newspaper article was published, which led to several local teachers indicating interest in the kits.

Additional Data Sources and Analysis

In addition to the course assignments described above, a focus group interview was conducted three and a half months after the course ended. Considering that the pandemic was still at large, the hour-long focus group interviews were conducted using an online meeting/video conferencing platform. The following questions were asked and the participants were able to respond to each other:

- Have you continued your nature notebook/field journal? If yes, tell us about how you've worked on the journal? If no, tell us why you haven't continued.
- Have your own outdoor experiences changed since the class?
- Has the pandemic influenced your personal attitudes and behaviors toward the outdoors? (If so, how? If not, why not?)
- Where do you anticipate applying for teaching positions (urban, suburban, rural)?
- How do you anticipate/see yourself using outdoor education in your future classrooms?
- Where do you see yourself conducting these activities (classroom, school grounds, virtually, field trips, other)?
- Which specific activities/experiences from the course do you plan on using?
- Why does this method of experiential teaching/learning matter to you and/or your future students?

The data were analyzed using a constant comparative approach along with an inductive analysis. Using the focus group responses and course assignments, we looked for emerging themes and patterns that may be distinct for this group of preservice teacher educators. Focus group responses were transcribed and entered into an Excel spreadsheet. In addition, relevant quotes from assignments were included into the spreadsheet. Initially, to identify themes, the responses from all participants were reviewed at the same time and in random order. The resulting themes and subthemes, along with examples of responses for each, can be seen

below. At this point, each statement was coded including the participant name (a pseudonym) and then the data source (i.e., Joe. Focus_GroupQ1).

- *Increased Perception/Observation* - “I was always connected to nature but it’s now intensified” (Greta. Focus_GroupQ2).
- *Curiosity (subtheme)* - “more outdoors during free time ... more curious ... more interested” (Naomi. Focus_GroupQ2).
- *People Interacting with Nature More Often* - “I’ve noticed more people while visiting parks” (Elizabeth. Focus_GroupQ2).
- *Benefits of Being Outdoors (subtheme)* - “I found that being out in nature is rejuvenating for the mind, body, and soul” (Marjory. Upstander_Project).
- *Incorporation of Outdoor Education into Teacher Practice* - How are students expected to have positive feelings towards nature, if they never go outside and explore it? (Donella. Media_Response8).
- *Online Learning Incorporating Outdoor Experiences (subtheme)* - “there are ways to use nature with technology” (Gus. Focus_GroupQ9).

Results

Increased Perception/Observation

Almost all of the participants’ mentioned they were more “more interactive and observant in nature” (Aldo. Focus_GroupQ1) as a result of being in the class and this behavior continued through the summer. This was amplified due to the COVID-19 pandemic and study participants actively engaging with outdoor experiences since they were spending so much time indoors as a result of social distancing and protective measures. While not everyone continued with the nature journals (i.e. Naomi, due to a heavy work schedule), everyone noted that they felt more observant when they were outdoors. A particular activity conducted during the class (before distance learning was enacted) was mentioned by multiple people. This was done while at an educational center in a nearby park and it involved each person selecting a leaf, observing it very closely (using a hand lens) and then turning to their neighbor in order to describe what they noticed on their particular leaf. This experience helped the students see what is often overlooked, in something ‘small’ like a leaf, and the importance of taking the time to look closely. As Elizabeth stated, her outdoor experiences “expanded in the sense of not only appreciating the outdoors, but being aware of your surroundings in them as well. I do notice the ‘small’ things more” (Focus_GroupQ2).

This sentiment was supported by Naomi when she responded to a reading

earlier in the semester...

I [selected this quote] because it emphasizes the importance of not only observing nature, but sharing these observations with others so we can use them for a greater good. (Naomi. Media_Response4).

Curiosity (subtheme). As a result of this intensified perception of nature, participants' curiosity about the environment was also piqued.

My outdoor experiences have changed 100% since this class. In the beginning, I was completely closed off to nature as a whole. For an example, I wasn't interested about studying animal tracks, learning about different [sic] or simply just going outside. This changed tremendously through the duration of our class. Now, I see myself getting super excited about realizing different things and how they work in the world around us. (Donella. Focus_Group_Q2).

As Donella notes, for her, increased curiosity was a by-product of spending more time outdoors. The face to face classes always incorporated a hike during the classes and study participants continued to walk around their neighborhoods, hike in the parks or explore more natural spaces. In particular, Donella was initially reluctant to participate in the hikes but that changed over time. As Rachel states "It's all about the inspiration, the awe, the wonder" (Nature Journal).

People Interacting with Nature More Often

While participants were spending more time outdoors themselves, it was noted that other people were seen out in parks and in nature as well. During the focus group interview, Aldo (who works as a nature guide at the national park nearby) said that the park's attendance had gone up 162% since the start of the pandemic and he felt that this was due to a "new appreciation" for nature and that "there's not much else to do". This was seen by some to be a very positive thing. At the same time, there was anxiety due to the uptick in people using outdoor spaces. Rachel noted that the "pandemic forces you to do something different to stay away from people – hiking, trail running, etc." but she also explained further that it was "harder to avoid people in nature" and that it made her "uncomfortable" since they weren't "following the rules and it was not as fun" (Focus_GroupQ2). Naomi was actively "looking for new places to relax where there are less people" (Focus_GroupQ2&3). Other pertinent human/nature observations included that in one sense, the natural world on a global scale was responding positively to less human impact because of the pandemic (Donella. Upstander_Project), while others still noticed more local pollution in natural areas due to increased usage and felt compelled to engage in stewardship action in cleaning up litter on her hikes (Elizabeth. Focus_GroupQ3).

That said, the overall impression was that study participants felt people should be more involved in outdoor activities, especially during these challenging times. Aldo explained in his Upstander Project that ...

One way that we can foster a sense of connection to nature... is to provide multi modal experiences to citizens who are currently stuck at home due to the coronavirus

pandemic. This will give citizens something to do during quarantine while also educating them on the nature around them!

Benefits of Being Outdoors (subtheme). The benefits of spending more time outdoors were also noted frequently. For example, “nature is healing” (Rachel. Focus_GroupQ8). However, while the benefits were seen as personal “I found that being out in nature is rejuvenating” (Marjory. Upstander_Project) such benefits were extended to the educational setting as well, for both students and teachers ...

The mental health of a teacher is just as important as the children there. Of course, we put students first, but how can a teacher teach effectively if he or she is not fully in balance? Simply put, the outdoors is a natural prescription for positivity. (Greta. Media_Response_8).

For students, the benefits of having contact with nature is seen to help reduce stress and “how a classroom affectively [sic] functions” (Harriet. Upstander_Project). These sentiments can also be seen when participants talked about incorporating the outdoors into their future teaching practice.

Incorporation of Outdoor Education into Teacher Practice

The overall consensus among participants was that it was important to include outdoors experiences into their future instruction.

Teaching lessons in nature provides unique opportunities for students to engage in their surroundings and become immersed in the classroom content. With the ability to see, hear, touch, and smell the content discussed in class, it also takes their full attention. Because of their increased interest and attention to the content, teachers can do much more in less time. (Aldo. Media_Response_8).

Equally interesting, participants also began to realize that it would not be difficult to do so. Using nearby natural settings, even the school grounds, would be important in order to get “students out there” (Greta. Focus_GroupQ5). Recognition that there are green spaces within urban environments that can be used for instruction or to foster advocacy for the environment was also apparent. As Rachel stated “students’ curiosity stems from their home life and their role models. They need someone else to be excited about science first so that they can see it is not at all bad” (Upstander_Project).

Further, it was felt that PBL strategies could be incorporated to “teach problem solving, get outside, and have it be hands-on” (Greta. Focus_GroupQ5).

Some students may have never been given the opportunity to leave the city and it could really open their eyes. I think it’s also important to let them know that they don’t have to leave the city to still be able to care about the environment and enjoy certain aspects of nature. (Harriet. Media_Response6)

You don’t have to make a whole field trip to a nature preserve to get your students involved in the environment. If the school is nearby a patch of grassy fields or trees, sometimes that’s all you need to incorporate an environment-based lesson. (Greta. Media_Response3).

Online Learning Incorporating Outdoor Experiences (subtheme). When the [Un]Class switched to an online learning environment, virtual meeting spaces were used to meet with the students on a weekly basis. However, work with the nature journals continued and this seemed to be an important experience since almost everyone continued working on their journals and spending time outdoors. Using virtual learning platforms does not mean that a disconnect from nature is imminent. “With the pandemic students will be sitting more and spending more time at the computer - EE gets the brain working and the body moving.” (Gus. Upstander_Project).

The goal is not to entirely dispose of technology, but to lessen the amount of screen time and increase the amount of time spent outdoors. [sic] In hopes of the development of an appreciation and love of nature within my learners’ hearts and minds, which can lead to proper conservation of our current environment in an ethical view of land. (Naomi. Upstander_Project).

Conclusions

Despite the challenges presented by the COVID-19 pandemic in Spring 2020, the authors feel that the objectives of this [Un]Class were fulfilled through the unintentional blended learning format. The quality of the online assignments, specifically the online Curriculum Kits, far exceeded the expectations of the authors in light of the significant shift from the original intention as physical kits that could be used at the field station with K-12 groups. Also, having assignments (such as the nature journals) that connected the preservice teachers to nature helped continue the emphasis on outdoor, experiential environmental education even while students were learning at their own residences.

The literature has noted that preservice teachers lack confidence, comfortability, and knowledge in environmental science and environmental education or working in outdoor settings. As a result, this could prevent teachers from actively engaging their students in EE (Barrable & Lakin, 2019; Bodzin, et al., 2010; Hug, 2010; Yavetz, et al., 2014). The preservice teachers that participated in the [Un] Class presented here, indicated improvement in these areas and skills sets and built on prior knowledge/experiences.

There have been increased opportunities for environmental education in “informal settings (natural history and science museums), outdoor spaces (school grounds, parks, other native land), and through environmental project-based community” incentives (Bloom et al., 2010, p. 97). However, the inclusion of environmental education methods and skills were also seen as important to include into teacher preparation coursework (McDonald & Dominquez, 2010; Tal & Morag, 2009; van Dijk-Wesselijs, et al., 2020). Participants in the [Un]Class indicated that they would continue to incorporate nature exploration and EE strategies into their own classrooms and will use a variety of techniques to engage a wide variety of learner-types. This would include:

- Using different spaces for engagement (classroom, schoolyard, field trips);
- Using EE specific activities (Field Notebooks, Curriculum Kits, Expert

Speakers, pre-existing EE Curriculum);

- Using a variety of delivery methods (digital, as well as face-to-face).

In addition, the preservice teachers in this study felt that incorporation of EE into their future classrooms would highlight a variety of benefits: mental health and well-being of students and themselves; interdisciplinary learning through PBLs in their school community; longer lasting learning; engagement of different learning styles (kinesthetic, visual, etc.); problem solving skill development; modeling positive interactions with nature; and developing environmental stewardship in their students. The skills developed through this course will hopefully empower teachers to get their students out into and interacting with nature, which will be more important than ever as it is predicted that a full 30% of organizations that currently provide environmental education experiences will be permanently shuttered and not survive the pandemic due to budgetary cutbacks (Collins et al., 2020). Unfortunately, it is likely that this reduction in available EE programs will disproportionately affect marginalized BIPOC and low-income communities (Collins et al., 2020). Experiential coursework, such as the [Un]Class described here, can provide opportunities and resources for preservice science teachers to incorporate environmental education into their future instructional practice during these very challenging times, bridging a vital and significant opportunity gap for urban learners.

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Learning and Becoming in Movement at the Intersection of Formal and Informal Science

Attending to Wayfaring, Intersectionality, Emotions, and Epistemologies

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Abstract

This paper builds on the policy statement of the Informal Science Education “Ad Hoc” Committee (Dierking et al., 2003), and unpacks what a convincing story of real world and lifelong learning in science might entail, as called for in the policy document. The paper takes that policy statement a step further by bringing a critical lens to current research on informal science education, resulting in calls for action in future research, that are illustrated through vignettes from three collaborative research projects. Throughout, we pay attention to the emotional work youth participants in afterschool and community programs are engaged in, marked by intersectionality. We argue that it is this kind of emotional work entangled with assigned positions and the authoring of new selves, that informal science practices can support. One vignette focuses on a girls-only afterschool space in which science is refigured through joint-work, another vignette explores a youths’ educational ecology and brings a space-time reading to learning and becoming in movement, while the last case focuses on navigations among epistemologies in the context of a water stewardship project led by Inuit. The three vignettes and subsequent discussions make possible the proposition of some new tools to think with for design studies and future joint projects committed to equity, deeply seated in and leading to expansive forms of participation, transformations and agency in and of science. In doing so, the paper aims to shift the performance range and positionality of learners and becoming in science and push us to attend more tightly to what happens outside the pipeline vision of science, and the manner science is entangled with learning lives.

Key words: learning in movement; identity; informal science; wayfaring; emotion; intersectionality; epistemology

This paper builds on the policy statement of the Informal Science Education “Ad Hoc” Committee (Dierking et al., 2003), and unpacks what a convincing story of real world and lifelong learning in science might entail, as called for in the policy

document. The paper takes that policy statement a step further by bringing a critical lens to current research on informal science education, resulting in calls for action in future research, that are illustrated through vignettes from three collaborative research projects.

The first vignette makes evident the dialectic between learning and becoming *in* movement and intersectionality. We do so through the study of a dialogue that emerged among high school girls within an afterschool program as they edited streeters. The latter implied asking other youth in the program about how science figured into their lives and then editing the answers into a clip responding to that question. We attend to the contradictions raised as they aimed to weave together stories of their lives as youth and as youth of color, living in an underserved community with normative science. The second vignette offers another view of learning and becoming in movement by expanding the space-time lens. It tells the story of Burak and his wayfaring and making of trails within an educational infrastructure that was accessible to him as a first-generation immigrant from Haïti. The third vignette engages with current epistemological assumptions in science by de-settling the taken for granted, calling for engagement with multiple epistemologies at the intersection of formal and informal science. The vignette offers a story of an Inuit-led water stewardship project in Mittimatalik (Pond Inlet, Nunavut), making evident in what ways on-going epistemological wayfaring constitutes learning and becoming in science. Members in the community of Pond Inlet sought a partnership with a community organization that offers support and resources for Inuit-led projects. That partnership translated into a three-year project, implying the monitoring of water quality in local streams, with results then guiding local and regional decision-making and the planning and protection of community sourced water.

Throughout, we pay attention to the emotional work youth participants in afterschool and community programs are engaged in, marked by intersectionality. We argue that it is this kind of emotional work entangled with assigned positions and the authoring of new selves, that informal science practices can support given their unique role and potential for becoming safe spaces, marked by the development of deep relations and solidarity that result in bonding capital (Nasir & McKinney de Royston, 2013). Afterschool or community science practices essentially can become “thick places” within which it is safe for minoritized youth to push boundaries of science and disrupt and challenge who can be a science person (Duff, 2010). The three vignettes and subsequent discussions make possible the proposition of some new tools to think with for design studies and future joint projects committed to equity, deeply seated in and leading to expansive forms of participation, transformations and agency in and of science. In doing so, the paper aims to shift the performance range and positionality of learners and becoming in science.

Theoretical Grounding: A Mobility Lens

Working in the traditions of sociocultural theory, anthropology and the learning sciences, we understand learning and identity in science as “embedded in our lives over time” (Sefton-Green & Erstad, 2013, p. 2). A focus on learning lives in science essentially pushes us to focus on learners’ navigations of opportunities, for-

mal and informal, that then become the building blocks of their lives and the kind of science literacy and kind of identity work in science learners engage in and aspire to. It assumes that we are all in contact with science in a multitude of spaces and at many different moments in time. Learning is understood as implying shifts in terms of children's and youths' thinking and understanding of science and its key concepts, next to shifts in forms of participation in practice (Lave & Wenger, 1991; Nasir, 2012). Learning is also tied to identity and about becoming a certain kind of person (Holland et al., 1998). Identity is understood as dynamic, grounded in the individual's history and complex trajectory and perception of who one has been, is, and can become, given ascribed social categories by cultural groups and settings, that are then negotiated, picked up or rejected by individuals as they author their own selves in line with desirable identities in science (Nasir, 2012). As such, an identity in science, like learning, is never accomplished, but instead, dynamic, continuously changing and in the making, and marked by the structure-agency dynamic. It is the dynamic process of learning and identity that has to be understood at multiple levels simultaneously, the macro (structure) and micro (agency in practice), and over time. This led to an interest in the study of learning and identity *in movement*, implying the study of "how moment-to-moment interactions related to, and could be made to relate to, broader contexts in which they could become consequential for learners" (Juwon & Shea, 2015, p. 2). It calls for a focus on the accrual of practice. In line with this argument, Barron (2010) documented the manner engagement with and an interest in science or other subject matter develop over time, while Wortham (2006), for instance, focused more tightly on how learning and identity as a certain kind of person takes hold over time in practice. These studies attend to different timescales of objects and artefacts and their role in mediating connections among practices and the becoming of a science person. What unifies these studies is the assumption that learners are agents who "disrupt flows of ideas, practices and people across spatial and temporal orders" (Juwon & Shea, 2015, p. 288).

At the same time, Leander and Hollett (2017) critique studies that focus solely on "connecting the dots" of activities and representational reading of lifelong learning and propose a change in focus, from understanding "learning across settings to learners crossing settings" (p. 1). They suggest a focus on embodied experience of space-time, and ask how understanding this experience, as it moves, might yield insights into the broader theoretical and methodological challenges of understanding learning across settings" (p. 2). Essentially, they call for a focus on "emergence (wayfaring)," and "pushing away from static representationalism" (p.2). In light of this argument, the notion of wayfaring is useful "to describe the embodied experience of this perambulatory movement" (Ingold, 2011, p. 148) and to show in what ways becoming in science unfolds along paths as *one is in movement*. The wayfarer is entangled and embodied in that movement as the wayfarer "threads his way *through* this world" (p. 151), suggesting that "wayfaring is our most fundamental mode of being in the world" (p. 152). Wayfaring implies the making of trails, and the leaving behind of trails, with the crossing of trails then leading to the emergence of knots. Yet, Ingold warns us to not think of knots as a place or point one travels to, but instead, calls for imagining knots as a "tangled mesh of interwoven and complexly knotted strands" or the "binding together of lines" (p. 152). He essentially argues that "knots, and the threads from which they

are tied are lines of wayfaring” (p. 149).

Building on the idea of mobility through the lens of wayfaring in this paper, we assume that coming to know and be in science happens through living, moving and sensing the world of science, implying embodied forms of learning and becoming in movement. In line with Ingold’s argument, we argue that we need to attend to “the entire meshwork of intertwined trails along which people carry on their lives” (p. 149). It naturally calls for enlarging the unit of analysis by attending to the manner learning and identity in science are entangled with other disciplines and developmental tasks, and marked by social, racial, gendered, economic, and political conditions that constitute those relations (Nasir & Royston, 2013). To understand “the complexity and hybridity” of science learning and identity as wayfaring naturally implies attending to the “complex, polycontextual, emotional and intersectional self” (Avraamidou, 2020). Hence, wayfaring is never neutral but marked by emotions and intersectionality that do something to our lives. As noted by Avraamidou (2020), “we live in and through emotions” in different ways, but we also live our complex political relations through emotions, expressing feelings tied to oppression or inclusion, or the joy of doing science or frustrations about being excluded from science, given its hegemonic nature. It led to the two questions this paper addresses:

1. How does learning and becoming in movement and by sensing the world of science and self in relation to science take form and constitute learning lives, at the intersection of formal and informal science?
2. How is such learning and becoming entangled with and marked by emotions and intersectionality?

Methods

We draw from qualitative case studies of three different out-of-school science programs. The first vignette was crafted from conversations that emerged in Convo-Club, a girls’ group run by a community organization (CO), reaching out to ethnically diverse youth in an urban center. We ran science activities within that club for sixteen weeks in 2016, leading up to the co-creation of a video documentary that we refer to, a story about science in the lives of the youth from the CO (Gonçalves et al., 2013). The club had six regulars, including Shanice who is of Black Caribbean descent and volunteers in the club. Sharon, Kelly and Caileigh, ranging in age from 17 to 18 years of age, and Sarah, 13 years of age, are all of Irish Canadian heritage, and finally, Karen who was 14 years old at the time, and is biracial (Irish-Canadian and Jamaican-Canadian background). We focus on a discussion that emerged as the girls were editing the streeters and aimed to co-construct a coherent story from the data they had.

The second vignette focuses on one youth whom we got to know as he participated in a four-week summer gardening and entrepreneurship program in 2018 that we refer to as ‘Vegetable Lane’, offered through a community organization we refer to here as ‘ruelle’, that reaches out to schools, youth, and families in underserved communities. We tell a partial story of Burak, a youth participant who immigrated to Canada from Haïti with his family in 2010, following the earthquake that devastated the island. We relied on fieldnotes, transcriptions of interactions from

video data, arrived at through interaction analysis among the research team (Jordan & Henderson, 1995) and interview data, to develop the story shared here.

The third vignette emerged from an ethnographic collaborative project that implied the joint documentation of a water stewardship project together with its project director and an involved community organization. The latter offered research tools and other supports given its commitment to promoting Inuit youth leadership and stewardship in Inuit Nunangat. In the vignette we rely on conversations and written documents gathered in the context of a qualitative case study of that project which implied observational notes from visits to the community and the water monitoring activities and collection of videotaped interviews of its participants and instructors from 2015 to 2017 (Spring 2015: 3 youth participants; 2 instructors; Fall 2015: 2 youth participants; 2 instructors; 2016: 2 instructors). For this paper, we center the voice of the project director and the manner he described the project and its benefits to the community.

The crafting of the vignettes for this paper was guided by our positioning as bricoleurs in ways described by Kincheloe and Berry (2004). Most important, we selected data sets to craft a story that would “fit the phenomena under study” (p. 101), while making “use of perspectives of multiple individuals coming from diverse social locations” (p. 102). In doing so, and through further iterative processes of re-reading the larger data sets, we were able to craft vignettes that are brief yet do offer rich insights and suggest new possibilities by centering voices of youth and adults still too often silenced in research in science education. We do recognize, however, that these stories are partial, and that many others could be told. Taken together, however, they offer rich insights in light of the research questions which guided the selection and crafting of the narratives.

RESULTS

Vignette 1. Sensing the Worlds of Science in a GirlsClub

The participants in the ConvoClub were busy figuring out what interview clips to use of their peers in their video documentary about how science figures in their lives. They had interviewed four male peers and regular participants in ConvoClub about how they think about science and how science figures in their lives to then inform others about how science is all around them. As a group, they tried to identify common themes among the streeters (video-recorded on-the-spot interviews) they had collected. The facilitator of the group tried to guide them through that challenging process:

Facilitator: Most people [interviewed by the girls] think science is boring, most people... don't know that they do science in their everyday lives. So, did you wanna keep all those little clips, where people say “I don't know”, “I really have no idea”...

Sharon: I think so.

Shanice: I think it's a bit true

Sharon: Yeah.

Sarah: The truth

Shanice: I don't think people actually think about using science every day. Like you go to school 'cuz they're supposed to teach you that there's science all the time, and blah blah blah

Shanice: But nobody remembers science at school.

Sharon: Unless you have to sit and think about it. 'Cuz even when you asked us, we were like "oh..."

Facilitator: Yeah. I know. It is kind of a difficult question to just bring on people.

Sharon: That's why [Bear] said he felt stupid.

The brief exchange above is telling of the hegemonic power of school science. To define science as boring can be read as a manner to save face in light of being positioned at its margin. That vision and positioning also silenced the youth when it came to name how they engage in science in their everyday live. The girls who interviewed the boys, had previously deconstructed that narrow vision of science through dialogue sessions and activities in the girls-group. Those activities helped them develop a vision of science as deeply grounded in and related to their everyday experiences of romance and relationships. It resulted in a new framing of science and authoring of selves as science savvy. Both were experienced by the girls as empowering, resulting in the observation that "there is science all the time" yet "people do not "actually think about using science every day" as further made evident in the ensuing dialogue, following the shared viewing of another streeter they had collected:

Facilitator: So... he [boy interviewed] said he's not interested in science outside of school.

Sarah: And then he does photography, so then that's science...

Kelly: And at the end-

Sarah: And then at the end he loves science.

Kelly: He's in love with science.

Facilitator: Yeah.

Sarah: Because he couldn't realize that photography was science. Yeah!

In this case, photography was a passion for Pedro, yet he did not see it as a form of engagement with science. Yet once it was identified as such by Kelly, it supported Pedro's authoring of self as somebody who "loves science" or as Kelly put it, "he's

in love with science.” Interestingly, and as noted by the facilitator, “the only person who knew something about how science figured into everyday life was David, who said “yeah, moving and walking.” The conversations that day ended with a focus on the take-away message from the streeters as follows:

Facilitator: What does listening to all of these interviews tell you about what people think about science?”

Sarah: That’s boring and that they don’t know very much.

Facilitator: Ok. So...

Sarah: I know, eh. Yeah. Yeah.

Facilitator: Boring [writing it down on a poster board]

Shannon: That there’s no single definition of science. It kinda proves the point.

Facilitator: Proves what point?

Sharon: That there’s no single definition of science. And like what science means to one person is not what science means to the other. Because he couldn’t realize that photography was science. Yeah!

Facilitator: ...ok, so we know that people think that science is boring and they don’t know very much about it. Ah, there’s no single definition of science, it means different things to different people...

The girls explained well the manner science was lived through emotions, noting how a science perceived as boring, naturally results in a disconnect with science. They craved a science that was interesting and somehow entangled with who they were and were becoming. While the video documentary led to many conversations about science and their own identity in science, it became clear over time that talking about science and connecting science to their everyday lives was a tool to refigure science in ways relevant to their lives, which they experienced as empowering, as the following dialogue also makes evident:

Facilitator: Do you think that most girls are interested in science?

Caleigh: Probably not.

Facilitator: Why not, do you think?

Caleigh: ‘Cuz they’re more interested in like their hair, and like their makeup, and like being popular, ‘cuz like science doesn’t necessarily go with being popular, being like in the cool clique, so girls like being in the cool clique.

Facilitator: Do you think that’s more normal for boys to do science than girls?

Caleigh: Ah. Probably. I think maybe yeah. ‘Cuz girls are more like I think we’re more like: We don’t wanna like get our nails ruined, or we don’t wanna like get something on our clothes, or like we don’t want this chemical doing something with my hair, or like if it’s humid and you don’t iron them, they’ll be puffy, like guys are just “I don’t care”, do whatever you do.

Given this exchange, we wondered about the value of our conversations in ConvoClub. They had given the girls an opportunity to deconstruct such gendered discourses, at times also marked by race, about who can be in science or a science person. Yet, such gendered and hegemonic images and practices did continue to define who they could become in science outside ConvoClub. Outside ConvoClub, to be interested in science was about becoming somebody else, somebody who did not value girly things like “getting nails ruined” or “getting something on our clothes”. To be an insider to science meant they had to reject who they really were and wanted to be – proud girls and for some, proud girls of color despite growing up in one of the most underserved communities in the city and lacking access to rich and engaging science in their schools. The dialogue hints at the emotional work such identity work implies and the manner intersectionality marked their positioning in science. We talked multiple times about differences between school science and the science in ConvoClub and how the latter had no currency in school yet was a form of science they enjoyed engaging with and could see themselves identify with.

Implications

The vignette makes evident how emotions are entangled with positionings and authoring of selves in science. On the one hand, the club became a safe space for the girls to engage with and deconstruct science and who can be in science in ways they never had an opportunity to do elsewhere. The study confirms that informal educational settings can become particularly important spaces to engage in such a deconstruction, to voice concerns about the manner science positions and disempowers, to share felt emotions and struggles, and to reposition selves within that complex landscape of meanings and relations with science. ConvoClub supported the girls’ engagement with multiple possible selves that were co-constructed through dialogue and practice. In that sense, the activities in the girls’ group encouraged new forms of wayfaring and the leaving of new trails and learning and becoming in movement. While the activity in ConvoClub was short-lived, it became a safe space to raise personal struggles, share emotions tied to a disconnect with elite science without getting in trouble. It was a place where some foundational work could get done among the girls “for continual science work” (Katz, 2017). The club supported an exploration of science identity as emergent from and tied to a complex “landscape of becoming” (Avraamidou, 2020), making evident how this kind of identity work in science is part of a lifelong ongoing process of wayfaring.

Vignette 2. A Learner Crossing Settings

The Rooftop Garden. Today was the first day of the camp which implied work in the

rooftop garden. Jane, the instructor, engaged the youth in a plant identification activity. One of the boys who had participated in the activity before took the lead in writing down the names of identified plants on a piece of paper, while the others helped out. They all stopped by the nettle plant given a sign “dangerous”. Jane explained that the plant burns the skin upon touch. As they moved on with Jane, she gave them clues that facilitated plant identification. She also encouraged them to touch, smell, and taste, especially the herbs. Youth wanted to know more about what makes the skin burn when in touch with the sap of a nettle plant. Jane explained the liquid in the stem that results in a burning sensation upon touch. The youth then explored the many types of mint they grew, which made one youth think about ‘curcumen’ and ask if they could grow it here. Jane explained that it is a root and that she had never seen it grow in Québec. Another youth offered to bring a book from home, that explains all about it. They then talked about factors that make for a healthy rooftop garden. Jane talked about the mistake of planting just one specimen, as it may result in the contamination of other plants and loss of harvest. After their break, they were asked to water the garden. Burak and other youth filled up the watering cans, while others took hold of the hoses, watering each other and the plants, given how hot it was. [Journal Notes, July, 2017]

The vignette makes evident some of the forms of participation gardening supported. Youth learned more about some plants by “dwelling” in the rooftop garden and identifying crop by touching, smelling, and eating, while learning more about what makes for sustainable gardening, and the kind of care gardening implies, like watering. After one week of gardening, the team transitioned into the kitchen where in smaller teams, they baked different goods with the vegetables and herbs from the garden, for sale at the market. In this vignette we center Burak’s forms of participations and positionings in the program by his peers. It was Burak’s second year of participation in Vegetable Lane. Burak’s Carribean background and history of immigration from Haiti to Montreal positioned him initially at the margin of the local school system given struggles to follow along in French, making him repeat a grade level. At the same time, he remembered the activities offered by ruelle in his elementary school as engaging, which then led him to continue his participation in Vegetable Lane. Burak’s team made brownies with mint from the garden. The following exchange emerged as Burak was cutting mint:

Theo: Wow, you are too good at it! You got experience.

Burak: Ha, ha, ha, yes, I can say, they taught me, kind of. The other one who was here before (referring to the instructor)

Theo: Oh really?

Burak: Yes, there was somebody else here before, not her. [July 11, 2017]

Burak’s embodied expertise in gardening and preparing produce for cooking was recognized by his peers, which led to his sense of empowerment. He referred to his peers and instructors as his friends, “they are my friends and I appreciate them a lot, they are the kind of people who are very nice and it is a pleasure and special treat for me to work with them.” Burak’s emergent expertise and recognition by

his peers as “somebody who can do all these things”, led to pride and positive emotions. Burak developed a positive disposition towards the program which led to full engagement, something Burak noted in the interview and which was not the case the previous year, when his form of participation implied in his words, “just hanging out with friends”.

The team also spent one week in the science laboratory, making soap and bath balls for sale at the market. Burak was again recognized by one of his peers as an expert, a positioning the instructor also approved of, tapping Burak on his shoulder. That embodied recognition followed after they struggled measuring the ingredients for the bath balls. Burak knew that the scale they used was inaccurate, giving often different readings. The instructor was quick to blame Burak, “you must have read the weight wrong.” Yet, in the end, she realized that the scale was broken. His peer, Elias, positioned Burak as knowledgeable by emphasizing, “well, you see, it was Burak who was right.” While the instructor nodded, Elias added “so let’s show some respect for Burak” to which the instructor responded by tapping Burak’s shoulder, noting, “hey congratulations, that’s great!”

The group was also coached by professionals in marketing strategies tied to the start-up of an enterprise. In the brief exchange below, a group of youth was preparing a slogan for a poster to attract customers to their market. Interestingly, their initial focus on a catchy slogan turned into an exercise in French grammar:

Theo: point, it’s your goal

Burak: No, no, no, ... it’s about helping the future generation

[Aider les generations futures]

Theo: It’s your mission to help future generations

[C’est notre mission d’aider des générations futures]

Burak: No, actually, it’s the opposite

Nassan: The future generation [La generation future...]

Burak: It’s your mission [C’est notre mission]

Theo: Yes, help (aider) with a (« ez ») [suggesting the verb needs to be conjugated = aidez des generations futures. [July 25, 2017]As they were creating a slogan for the poster board, they got caught up in a disagreement about the tense of a verb. Burak was right again here too, making the group write the slogan in ways he proposed, positioning him as an expert in yet other ways.

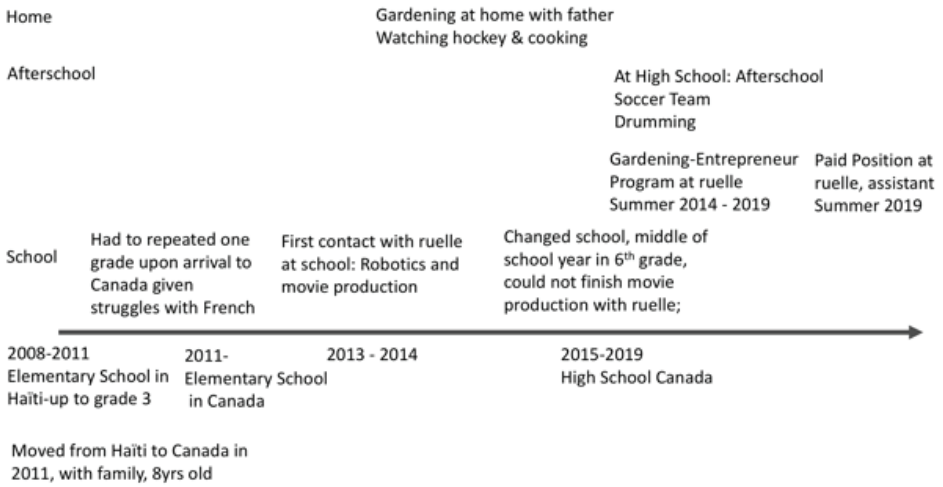
The team took part in the sale of everything at the local farmers market at the end of that week. Burak claimed to have “participated for real only now” in his second year in the program. He shared his feelings with us as he was arranging flowers for the upcoming sale at the local farmers market. He came to the program to socialize, whereas this year, he valued the program for the many things he learned,

especially about marketing. He saw the latter as crucial for his future, permitting him one day to run his own business. Program participation also “helped me to get to know myself better”... “I realized that I like to eat, I like to create new recipes” and when in school, “some would ask me for advice or some information, and I could share things I learned about in this program.” He also talked about making soap and bath balls with his father, who noted how valuable such ways of knowing are for running a soap business one day.

In the end, Burak participated in the program for four consecutive years. The analysis above suggests that instructors and peers in the program positioned him as somebody who is knowledgeable and has important contributions to make. This was not how he was positioned in school, at least not always, as we found out when doing a timeline of his educational pathway during an interview in 2019. Burak vividly remembered his family moving to Quebec in Canada, and him having to repeat a year of schooling at the beginning, as he could not follow, according to his teacher at the time. It was emotionally challenging for him to be held back. Another emotionally charged memory was his report card and the losing of points which then obligated him to stay inside during recess or stay on after school. It was something that made his mother very upset. At the same time, Burak also remembered teachers who encouraged him. For instance, he struggled with English in high school, as languages did not seem his strength, yet his English teacher went out of the way to help him pass the course. In contrast to school, the aim to socialize with peers initially attracted him to the gardening program. Yet, as Burak explained, over time, “the program helped me to understand myself in new ways, what I am good at, what I am not as good at, what I like to do with my future and what I would prefer not to pursue later on. I also developed a real team spirit this year.” His dispositions towards the program and himself changed. He felt empowered within the program and experienced agency in ways he valued.

Taking on the lens of wayfaring, the analysis makes apparent the manner Burak lived the program through interactions with others who treated him with respect and dignity. Burak was recognized as a youth who can succeed and who brings strengths to the program. That positioning made him live the program in positive ways and did something to him. The program became a “thick place” for him, as his reference to it as a second family suggests (Duff, 2010). In 2019, Burak was employed by Vegetable Lane and helped out in the family gardening program. As summarized in Figure 1, wayfaring became marked by his time at Vegetable Lane in important ways.

Figure 1. Burak’s timeline of activities that were important to him



Burak’s timeline also makes evident moments he came in contact with science through ruelle. With his class, Burak participated in a robotics project with ruelle, and later, also pursued a project in movie making, in addition to participating in Vegetable Lane during the summer. Yet, none of these activities gave him a sense that he could become a science person. Instead, he was eager to use science as a tool – like making soap – to one day run his own business.

Implications

The vignette makes evident how important community based educational spaces (CBES) can be in supporting youth development and well-being which we understand as essential to learning and wayfaring in and beyond science. Quality CBES resist deficit views of youth and offer youth opportunities for embodied learning and becoming that are emotionally engaging and empowering (Baldrige et al., 2017). Burak’s story makes evident how being treated with dignity is key to his well-being and educational achievement, but also sustained his engagement with ruelle over time, even when he moved away from that neighborhood with his family, which distanced him physically from its location. Engagement over time led to many empowering learning experiences. Most important maybe was the opportunity for Burak to give back, as a youth mentor and employee of the organization. In that sense, my research team understood ruelle as a key “resource, helping youth connect with each other, their community, and adult allies” (p. 388). That is, Burak’s positioning as lacking, as needing to repeat a grade, as being a problem

in terms of his behavior by some educators, led to frustrations and exclusion. Yet, through his ongoing presence at ruelle, he built a system of relationships that sustained him and positioned him as somebody who *can* become educated. Burak's wayfaring also shows that ruelle offered opportunities to engage with science, initially through an activity in robotics, and later through gardening. These were opportunities for Burak to engage in "continued science learning" for his own sake (Katz, 2017). That learning was also embedded within a rich set of other learning opportunities, over time, as Figure 1 makes evident. The vignette suggests that Burak was "banking the learning for perceived future need" (ibid, p. 14) and was imagining himself as a future entrepreneur. He was becoming the kind of "competent outsider" to science that will have the skills to one day engage with science in locally relevant and adaptive ways (Feinstein, Allen, & Jenkins, 2013).

Vignette 3: Stewardship of Water and Land in Nunavut

The third vignette speaks to the manner water supply in Nunavut is tied up in complex ways with issues of climate change such as "receding sea ice and glaciers, decreased stream flow and dryness, increased temperatures and rain events." It led to concerns, in many communities, about the quantity of drinking water that is available, but also its quality. In Pond Inlet, Nunavut, the site of the stewardship project we focus on here, the water lake serving the community was created during the settlement period in the 1970's, and still serves the community today, a community that has increased substantially in terms of its population and water needs. To rely on one water source only is risky. Threats to water quality are multiple, some tied to a long history of contamination of the land, others to challenges tied to disposal (Johnson, 2018). The community relies on trucked water delivery and sewage collection, another challenge in terms of water quality. To ensure health safety measures, Chlorine and/or Javex are added to trucked drinking water, a practice that started in the 1970's, according to the elders. Others referred to the addition of fluoride, and still others recalled the frequent "boil water advisories." Those forms of water management stand in stark contrast with the traditional water gathering practices of Inuit prior to settlement and still pursued today. As the youth in this project found out and shared in conversations with us, "elders prefer iceberg and multi-year ice for drinking water as well as water from fresh streams" given its taste. These concerns led to the project in the following ways, as described by its director:

We wanted to develop a project that would provide us with the opportunity to conduct serious research and answer the preoccupations of our community in a way that would build our skills and knowledge for the benefit of our community. We found out that the best way to achieve these goals was by taking the lead in research and manage it ourselves and when needed, request the help of researchers in universities and community organizations. I started this project given encouragement by community members and Elders, and wanted to respond to the concerns of community residents who complained of stomach illness. Our community had no equipment, no capacity back then to research water.

The project was deeply grounded in Inuit Knowledge Systems (IKS) yet open to the integration of and blending with Western Science and scientific methods,

as long as the program remained locally grounded, relevant, and empowering, contributing to the common good (Lipe, 2019). It implied a conscious move away from the domination of Western Science over Indigenous Knowledges or an add-on approach, as is still often the case. The project was deeply seated and committed to an indigenous ontology.

The project director also presented at numerous scientific meetings and had much experience navigating the Western World and Knowledge Systems. When attending a meeting in 2016, he was happy about a change he noticed towards more community-based and community-led research presented by Inuit. Yet, he still saw the need for “more community-based researchers to come and present their work and with their emotion, tell the audience how they feel. This is how it should be in the communities, no more colonial forms” of research.

The water monitoring project emerged from local needs and always stayed in the community. The director of the project was taught by scientists that he sought out for training through a collaboration with a community organization. That organization offered scientific and technical resources and support. The director describes it as “unique... to have been trained by researchers, and everything I’ve been trained at” which implied some training in laboratories at partner institutions and Universities. While not always trivial, it left the project director and his community with new tools and skills to pass on, to “now train youth in my way, because I can speak their language, and I can make them understand without losing them ... just living, being a part of a community, we understand how we can learn and work together. So everything I’ve been trained at I’ve trained my young Inuit assistants in a different way or in our language” deeply grounded in Inuit ways and guided by *avatimmik kamattiarniq* or the collective responsibility for all Inuit to act as environmental stewards and respectful guardians of wildlife and the natural world.

The project director would “like to see more programs and more opportunities” like this one, a reason that motivates him to continue, “that is one reason why I do this, so that there are more opportunities for youth, more money going in, whatever little money it is, it helps the little economy. I’d like to see more programs, and more opportunities when they grow up, so like there can be a path.” The project director was referring to his own path of moving back to Pond Inlet after having spent his childhood in an urban center and Western Educational System. Once back in his community, he could reconnect with his language and culture through work with elders and other community members. Thinking back about his youth, he notes how the youth he works with in the project have the opportunity to be part of an all Inuit Team, something that makes them proud, is unique, and not something he experienced growing up:

It’s a community driven project, community concerns, and it’s run by Inuit. And having an Inuit leader, just gives them pride, and they’ve said it time and time again. It’ll empower them, they can maybe do their own someday.

Pride makes all of us better. When you have something to be proud of, you have something to work for, everything’s easier to work. When you’re happy, you look forward to something. Being proud of what you’re doing, you’re happy, you’re your own boss, you can... like if a boss is proud, it will show with his workers, his assis-

tants and it will catch on. And being looked up to, having the assistants be proud of an Inuit project leader just helps, we're all happy, we're all proud of the work we're doing. It's for something, it's for community. I think it makes it so much easier and better. We can do a good job. It's very nice to get great feedback from elders who believe this is for one common goal and it's not run by southerners anymore.

The project director's ability in navigating epistemologies was put to use but also so much more, as he describes further:

The driving force to what I'm doing is the learning, taking what I've learned and helping and training others so they can understand. For example science has fancy words, I can take it, transcribe, translate it to something that regular community members can understand and if they can understand it, they'll be more..., the better they understand it, the more they'll get involved. And if we can get more and more involvement it's just gonna blow up and... they'll do their own thing. It won't be old fashion anymore - having southerners coming up to our arctic communities doing what they want - it's gonna be Inuit doing what they want. They can take the lead. They can do it [See Figure 2 showing some of the monitoring work].

Figure 2. Sampling at water lake (left); water flow observations and sampling in river (right)



Implications

The water stewardship project speaks to learning and becoming in movement tied to navigations among epistemologies and worlds of science. The project is about rebuilding relations that have been broken due to ongoing colonisation, relations to land, water, language, culture, elders and other knowledge holders, ways of knowing Inuit have always known to be true, while striving for the common good. The project also hints at ways of building research relationships that have to be re-established, implying some of the following kinds of respect: “respect your land; respect your laws; respect your Elders, respect your culture, respect your community, respect your families, and respect your futures” (Wilson & Hughes, 2019, p. 15). Research and joint work can then put in action those responsibilities to relations. The project described here took this to heart. The project director worked with elders to ensure the resurgence of Inuit ways of knowing, doing and being and build a solid foundation of the water stewardship project in this manner. By bringing youth together with elders, bringing youth on the land and in contact with water, the project worked towards rebuilding broken relations. The project led to a relational accountability that set it apart from Western Science and its underlying ideology which too often resulted in researchers flying in and out of the community to conduct their own research with no contributions to the common good of the community.

The project director also refers to the manner the Inuit-led monitoring project was driven by and contributed to “‘messages in our body’ and the feelings in our ‘heart and our soul’” (Wilson & Hughes, 2019, p. 11), which also set it apart from Western driven water research. That dimension became most evident to the project director when he attended presentations by Inuit about their own stewardship work. The vignette makes evident how science figures into our learning lives and how learning and becoming in movement imply navigations among epistemologies with the indigenous worldview being deeply seated in emotions, and entangled with community wellness and a wholistic framing of the world, and of science. That is also why indigenous knowledge systems in this case captures best what the project director describes, and is, as some suggest, “the missing link in scientific worldviews” (Lipe, 2019, P. 453). Learning and becoming in science in this instance is about rebuilding relations in and through movement among epistemologies and world systems, resulting in the rebuilding of respectful relations.

Discussion

Gutiérrez (2020) notes that “learning as movement was intended to unsettle how we see what counts as learning, where we see learning, and especially to imagine what new perspectives and epistemological footings are called for in attending to new sets of relations and spatial configurations.” The three vignettes offer a beginning to re-imagine learning and becoming in movement and at the intersection of formal and informal science. The first vignette looks at a practice committed to re-mediating girls’ interest in science through co-creations and engage in conversations that naturally emerge yet are telling of lived emotions entangled with different positionalities in science. The second vignette focused on wayfaring and knotting, documenting how learning ecologies emerge yet are also tainted by po-

sitionalities, emotions and histories in person. The third vignette explored navigations among epistemologies and how those position but also support new possible selves. We call for more work that carefully attends to mobilities, intersectionality and power, emotions, emergence, agency, and embodied learning and becoming in and through science in the real world, through joint-work and attention to mobilities, resulting in new imaginations of what could be. The vignettes offer important methodological insights into the kind of timescales we may need to strive for in future studies of learning and becoming in movement, in science, as well as the “attunement needed to illuminate and document the complexity of human learning activity” (Gutiérrez, 2020, p. 430).

What are some other new tools to think with for design studies and future joint projects in the field? What clearly stands out is the need for a more holistic vision of learning and becoming in science, entangled with subject positions that are political and continuously shifting, marked by intersectionality and lived emotions. A spatial reading of educational venues for deep engagement with and embodied science, also suggests that the co-creation of “safe spaces” to engage with science takes time, yet is highly valuable. Through engagement in the co-creation of such spaces researchers’ take on new positions that can then result in the joint documentation of a practice and its key components in ways that make evident what matters to youth participants. That kind of work challenges our own positionings and relations as researchers with the individuals, practices, communities and epistemologies that we work with, resulting in new possible imaginations of practices that are co-constructed, and that are at the cross-roads of formal and informal science (Gutiérrez, 2020). By expanding the scales of time, we can document deep and durable involvement with science in ways the cases hint at. But we also have to attend to different practices and to the manner learners are entangled with and deeply engaged with a science that is far removed from the pipeline vision (Feinstein et al., 2013). By attending to learning and becoming in movement through a focus on wayfaring, intersectionality, emotions and epistemologies across the three vignettes, the paper begins to unpack what this might imply, encouraging more work that looks more critically at “living and learning” which are “complex and cumulative” (Katz, 2017, p. 23), embodied, emotional, and political, while also deeply entangled with science, all of which constitutes learning lives.

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