Fall 2022

Citizen Science As Experiential Education In The Modern Classroom

Peter Swan

CITIZEN SCIENCE AS EXPERIENTIAL EDUCATION

IN THE MODERN CLASSROOM

by

Peter Allen Swan

A capstone submitted in partial fulfillment of the

requirements for the degree of Master of Arts in Teaching.

Hamline University

Saint Paul, Minnesota

December 2022

Primary Advisor: Karen Moroz
Content Reviewer: Jenny Ortner
Peer Reviewer: Camille Werner

TABLE OF CONTENTS

CHAPTER ONE

Introduction

Society has experienced unprecedented transformation in the 21st century - arising from the technological advancements of computers and smartphones, the proliferation of the internet and the introduction of social media into our daily lives. In 2022, the world is more digitally connected and dependent on these technologies than ever before. An increasing segment of the population is turning online for employment, education, commerce and community. Many schools abruptly had to adopt online classrooms and adapt to virtual learning during the initial lockdowns of the COVID-19 pandemic in March of 2020. This only accelerated the increasing trend of K-12 students learning remotely online.

While significant progress has been made in online education, it's still very much a developing practice and field of research, along with the fact that new software emerges constantly. An apparent challenge in remote learning is the lack of "real-world" interaction for the student. If students are only interacting with computer screens all day, they are missing out on the tangible, concrete learning experiences that come with engaging with the physical world. For instance, a science teacher may find it difficult to relay the principles and practices of conducting a science experiment without the "hands-on", experiential setting of a laboratory. Addressing this "problem" is the basis for this Capstone Project, which explores the more specific question of *"Can outdoor, experiential education be successfully integrated into modern science classrooms?"* This chapter will provide the context and background to this project and will outline how the research question will be addressed through the creation of a laboratory curriculum for a 9-12 Life Science virtual classroom.

Throughout the paper, the potential benefits and limitations in virtual instruction will be examined to identify solutions that will supplement and enhance the online learning experience for students. This secondary-level project will draw from the wealth of resources that already exist in experiential science education, collaborating with citizen-science initiatives through interactive websites and mobile applications. In this field-based laboratory project, students will remotely conduct scientific observations - collecting data for real academic studies - and they will practice the fundamentals of the scientific process, while also learning how to interpret and communicate their findings in a presentation and report.

Background/Rationale

Before pursuing a career in education, I was an undergraduate biology major working towards either a profession in health care or research. The core science classes were demanding and they usually involved lots of labs, reports and research. The idea of the research-driven program was to not just learn about science, but practice being scientists. Since I was somewhat undecided on a career, I used that time to explore a variety of sub disciplines through employment. I took opportunities in the fields of healthcare, environmental science, resource management and vaccine production. Eventually, I found a passion in science education.

As a teacher in training, much of my graduate program has involved learning about being a teacher by *being a teacher.* Along with the classroom instruction have been countless hours of observations, student teaching, practice lessons and so on. So, in a very simple way, I’ve learned to be a scientist by practicing science and a teacher by practicing teaching. While lectures and instruction are necessary, it's only when you’re fully practicing the craft that all of the theoretical knowledge finally becomes concrete and synthesized. This appreciation for experiential learning naturally brought me into the field of environmental education.

I continued the same approach during graduate school as I had in undergraduate: to get experience working in as many different roles as possible. I was fortunate to gain rewarding employment as an environmental educator for the Minnesota Valley National Wildlife Refuge, a trail guide and educator for Wilderness Inquiry, and a supervisor for a habitat restoration youth team of the Minneapolis Park and Recreation system and Mississippi River Watershed. What these organizations all had in common was that the learning came through providing experiential activities in the real-world. Students were left with a memorable experience and better understanding of the natural world and the scientific process. They gained practical and social skills while participating in something purposeful and meaningful.

There is a fairly extensive amount of research into environmental and experiential education, along with a multitude of organizations offering materials, training, and outreach opportunities for K-12 students in America. One initiative that I became involved with as an environmental educator is called “citizen science” projects. Citizen science is generally defined as academic research done with voluntary participation from the public. In a sense, it is crowd-sourced data collection.

Typically, an organization such as a university or non-profit will begin a large-scale research project that involves extensive data collection. That organization will then create an outreach campaign to recruit volunteers from the public, including K-12 schools, to help make and record observations that are included in the academic research. This type of program is most common in environmental and ecological research and some topics I’ve encountered are: estimating Monarch Butterfly populations, measuring rainfall and river water quality, identifying dragonfly species, and monitoring the seasonal variation in plant and animal species.

Oftentimes, the organizations behind these citizen science initiatives have also developed engaging and relevant curriculum for K-12 classrooms. For example, a secondary life science teacher could integrate the Monarch Butterfly population study into the curriculum of their unit on ecology. Most of these projects also include a mobile application for data collection and a website to access the study, along with supplemental educational materials. Within these larger studies are any number of sub-topics to explore for classes, and from my experience, these are some of the most engaging lessons for students.

After finishing the teacher licensure program, I was ready to explore how to implement these experiential activities into a traditional secondary classroom.

A secondary life science class covers a lot of material and standards - a teacher generally can't stay on any one topic for too long. There are limited opportunities to take the class out in the "field" or in the lab. So, there are certainly some logistical challenges on the teacher's end and it requires creativity to implement it. Still, you could demonstrate it in person and have the students collect the data later.

However, these opportunities largely vanished in the early months of 2020, as a pandemic swept across the globe and forced most schools and businesses to go into a series of lockdowns. Students now spent entire semesters online and instruction was given exclusively over webcam. Teachers would host their coursework and activities in digital classrooms. Outdoor, experiential "real world" education was put on hold.

As the pandemic drew on and schools adapted over two years, virtual learning became a fixture of modern education. The market responded and many innovative organizations emerged that offer alternative online education. Parents suddenly have more options than ever regarding meeting their child's educational needs. Homeschool groups also now have access to certified teachers through these platforms. It is quite evident that virtual learning will continue to have an increasing presence in K-12 education in the 21st century. The question is: how can you best offer students a meaningful and engaging learning experience in spite of the limitations of remote instruction?

I began my foray into virtual teaching in January of 2022, just as most schools had already returned to in-person learning. Still, a new market of digital education had emerged that brought lots of employment opportunities. I was living in the rural coastal area of California, where there weren't many available teaching jobs - so I accepted a job as a 9-12 Life Science instructor for a virtual education company, and began teaching and tutoring students over webcam sessions. So, at the start of this capstone project, I find myself in the first days of learning how to deliver lessons remotely. Once again, I'm learning how to be a teacher by *being* a teacher, and this paper and project will serve as the methodological framework for how to provide real-world lessons through this new venture.

Conclusion

Immediately I'm confronted by the obvious challenges of online teaching - the lack of in-person and real world interaction. This apparent limitation is the impetus for this research paper and accompanying Capstone Project. Again, this paper seeks to explore the question: "*Can outdoor, experiential education be successfully integrated into modern science classrooms?"*

I intend to deeply explore this specific research question by identifying the most relevant citizen science initiatives, connecting and collaborating with professionals in the field, and by designing the curriculum laboratory project for a 9-12 Life Science classroom that meets NGSS requirements and contributes to real-world academic research. In the chapters ahead, I will be conducting a literature review to highlight where the current trends in education are and showing what insights have been found to date. I'll also be laying out the methodological and theoretical framework behind the curriculum development.

The next chapter will dive deeper into the basis and background of the project through a thorough review of the literature. I will draw insights from the already established research in environmental education, citizen science, and virtual instruction. The literature review will also establish connections between researchers, practitioners and organizations in these areas. As these theories are synthesized and the trends in research are developed, I hope that the importance of the project will be more and more evident.

By the end of this project I intend to have this curriculum fully ready to be taught and I hope to find the opportunity to do so in the near future. This will be an experiential project about making an experiential project and this paper will be an autobiographical account of that process. My hope is that this work will help bridge the gap in online education, offering students time away from their screens and out in nature and the world, as I see this as an increasingly common trend for the modern science classroom. Why not use our amazing technology to connect together to better understand our world and selves?

CHAPTER TWO

Literature Review

Introduction

Technology and education seem to be interconnected throughout human history. As our mastery of a skill is reached or the design of a tool is improved, so too must the teaching of that newly acquired knowledge improve. However, in a time of such rapid technological advancement, are we ensuring that our pedagogical practices are developing at the same rate? How responsive has the profession of education been towards the societal march into the digital age?

This paper explores this central dilemma by asking the question: "*Can outdoor, experiential education be successfully integrated into modern science classrooms?"* This chapter provides a literature review of current research and historical developments in the areas of education, pedagogy, nature and technology. Several key themes have been identified, though there is considerable overlap between topics of study. The main themes of the literature review are: trends in modern education, digital classrooms, educational theory, environmental education, and citizen science.

This chapter will first explore the current demographic, socioeconomic and cultural trends in primary and secondary education in America and abroad. There has recently been a lot of public interest and a swath of research exploring the effects and aftermath of the COVID-19 lockdowns on K-12 students and institutions. This section will present the findings and opinions of various experts on contemporary education.

Staying on the broader theme of modern education, the next section will explore the literature findings on digital education, also referred to as distance learning, virtual classrooms, remote learning, etc. The topic of remote learning was central to much of the COVID-19 lockdown response - this section will look at the academic research on delivery methods, formats, and organizations as it pertains to digital education, while also highlighting new developments and potential areas of interest.

The following section is titled “Educational Theory” and it provides the theoretical and philosophical background for the project. What are the best practices in curriculum design and instruction and how can this be translated into virtual learning? This paper takes the philosophical approach of creating a student-centered and experiential classroom. More specifically, the curriculum models of Understanding by Design (UBD) and the 5E’s will provide the basis for the design of the project.

Next, the literature review highlights decades of research and development in environmental education in K-12 settings. Many studies have explored what makes an environmental program effective in the 21st century. This section compiles expert opinion and research findings on best practices and trends. This project will borrow from and integrate established and quality material that share a common interest in environmental education.

The last section of the literature review will present findings from expert research on citizen science in education. This is a facet of environmental education, but unique enough that it merits its own section. This topic has also generated a lot of research from the academic field, as it involves many large academic and scientific institutions. Again, this project will borrow from and integrate quality material from citizen science initiatives that align with the same goals.

Trends in Modern Education

Primary and secondary education in America has progressed a long way from its humble roots. There are more options for families than ever before. Many were unexpectedly forced to familiarize themselves with new platforms and delivery methods as schools closed down in early 2020. Over 50 million students and 124,000 public and private schools were affected by the pandemic in the United States - a fraction of the over 1.2 billion students in 186 countries globally being affected by the lockdowns (World Economic Forum, 2020).

The world-wide lockdowns presented a unique challenge to educators and families. Most organizations had to suddenly transition to distance learning, implementing new or seldom-used digital platforms and video conferencing. Most students were resigned to their homes and received their education through their devices. A survey found that 72% of American parents say their children spent more time on their screens after the outbreak and 93% of parents of K-12 students say their child received online instruction at least some of the time, with 70% saying that the online programs were helpful and easy to use (Pew Research Center, 2021). Across the globe, some degree of school closure was in effect for at least seven weeks in two countries, 8-12 weeks in 6 countries, 12-16 weeks in 24 countries and 16-18 weeks in 13 countries (Schiecher, 2020).

One apparent consequence of the lockdowns was a migration from public schools to homeschooling, an increase of 5.6 percentage points in the overall population and a doubling of total families homeschooling at the start of the 2020-2021 school year (U.S. Census Bureau, 2021). By the fall of 2020, approximately 11.1% of households with school-aged children reported homeschooling. As disruptive as the lockdowns were, they also provided a massive growth opportunity in distance education, which was already seeing an era of unprecedented growth.

Online education was already on track to become mainstream by 2025 (Palvia et al., 2018), with over $8 billion being spent yearly on hardware and software for education (National Education Technology Plan, 2016). The overall market for online education is projected to reach $350 billion by 2025 (World Economic Forum, 2020). Currently, public schools are providing approximately 1 in 5 students with a computer and this is expected to grow (Analytics Insight, 2020). In 2015-2016, more state standardized tests for K-12 were administered digitally, rather than with paper and pencil (Analytics Insight, 2020). Prior to the lockdowns, a survey was conducted of the 2017-2018 school year which found that 501 full-time online schools enrolled 297,712 students, including 300 blended schools that enroll 132,960 U.S. students (U.S. Department of Education, 2020). 46% of all virtual schools were charter schools (U.S. Department of Education, 2020) which have faced public scrutiny for the varying quality of the programs (Herold, 2016).

This push has come with substantial private and public support. The US Department of Education created a National Education Technology Plan to inform the next generation of educators (Analytics Insight, 2020). The goal is to create digital instruction that is individualized, differentiated and tailored to the specific interests of the students. The federal government has furthermore undertaken a massive effort to bring affordable high-speed internet, along with free online teaching resources, to all areas of the country. This initiative seems to build the infrastructure needed to enable universal access and use of technology. The US Department of Education is also encouraging districts to move away from physical textbooks and towards implementation of Open Digital Resources (ODR) (Herold, 2016).

“Distance learning” in the United States evolved over three centuries into “online” or “digital” learning. Distance learning began as an early form of alternative education, where lessons advertised in newspapers would be sent via the mail as far back as the early 1700s (Palvia et al., 2018). As technology advanced, so did the means of distance learning as radio, television and the postal service connected us. The University of Phoenix began using the first online education technology in 1989 and was offering courses on the World Wide Web in 1991. This trend progressed steadily with the advent of the internet and the concept of “hybrid” or “blended learning” took off at the turn of the millennium. These classes offered some face-to-face interaction along with online components. Blended classrooms made way for “flipped” classrooms, where educators try to strike a balance between in person instruction and at-home learning (Palvia et al., 2018).

The emphasis in academia has been on identifying best instructional practices and creating beneficial virtual environments. Just because a technology emerges, doesn’t necessarily mean that we will use it to its fullest potential. Simply moving a traditional-style classroom online is not enough to ensure quality (Guardia et al., 2021). The increased dependence on technology for teaching and learning as emergency courses were oftentimes implemented without the necessary time frame to fully prepare. Student concerns about isolation from peers, about mastering new technology and software and reduced quality of instruction all need to be taken seriously (Palvia et al., 2018). The harmful effects of technology and social media addiction also need to be taken into consideration by educators (Palvia et al., 2018). Implementing new technology and teaching methods does not mean replacing the existing models, but rather expanding on the possibilities afforded by the technology (Guardia et al., 2021). Guardia et al. argues (2021) that despite the drawbacks, technology still provides a viable solution to designing flexible educational models - adaptive to socioeconomic and cultural needs as they arise.

The technological revolution of the 21st century goes beyond just instruction, rather, developers are working on utilizing technology to aid in all aspects of education and learning - including cognition and memory, personalized assessment and extensive reporting and monitoring abilities (Guardia et al., 2021). Furthermore, the advent of artificial intelligence (AI) and virtual and augmented reality present another potential fundamental shift in education and human experience (World Economic Forum, 2020). A number of schools already use AI to identify where students are struggling, along with running an analytical program that adapts coursework to the individual learner's needs, identifying popular learning materials and methods according to their unique needs (World Economic Forum, 2020). “Intelligent pedagogy” has emerged, which involves using learning analytics to aid in the learning experience (Guardia et al., 2021). As digital learning becomes more mainstream, we will need to incorporate the best of our theoretical and practical understandings from centuries of study on education. The following section will review literature on virtual classrooms and digital instruction and highlight research into the effectiveness of various features of online learning.

Virtual Classrooms/Online Education

While online education has existed for decades, it only recently became a widespread phenomenon. Public schools have mainstreamed the use of remote learning ever since the first lockdowns brought by the pandemic in early 2020. Additionally, private schools, home school groups and many other organizations have adopted virtual classrooms into their programs. There is great potential for sharing information and connecting, but a challenge to substitute the value of in-person experiences. This section will address the most pertinent and recent research and methodology behind this pioneering field of education.

As the field of education incorporates this new technology, researchers have been tasked with the goal of identifying the best strategies to deliver effective education programs in the digital age. Some common obstacles to successful implementation have been identified by (Analytics Insight, 2020): instructors are resistant to new ways of teaching, leadership in local government and school administrators drive the change, professional development for instructors is lacking, and digital content isn't equally helpful (Analytics Insight, 2020).

Despite the obstacles, research into this topic generally finds online education to be as effective as face-to-face classrooms, while it does require different capabilities from students and staff (Gasevic, 2020). Means et al. (2009) did a systematic review of research literature from 1996 through July 2008 found over a thousand empirical studies on online learning and they found positive effects on learning associated with blended and online education, though they were surprised to find how few rigorous studies exist comparing face-to-face learning with online for K-12 students.

Earlier studies concluded that learning effectiveness was not significantly different from regular and online classrooms and that instruction combining face-to-face with online had a greater advantage than purely online classrooms. Variations in methods of online delivery did not seem to have a significant effect in their findings, though online learning was found to be enhanced by giving learners control of their interactions and in providing opportunity for reflection (Means et al., 2009).

The types of interactions in online learning have been analyzed in a meta-analysis that found each interaction (among students, between the instructor and students, and between students and content) is an important factor in effective online learning and argues that we must consider collaboration, communication and cognition in choosing our technological tools and that knowledge tools should be set up to increase the efficiency and effectiveness of learning (Abrami et al., 2012). Instructors should be aware of the ease of use of an overall design objective in which learners need additional guidance on using features of a digital program.. Furthermore, time (time to learn technology, time to set up infrastructure) has been found to be a major factor to consider when implementing an online curriculum and so simplicity and ease of use appear to be vitally important to successful programs (Abrami et al., 2012).

Some guiding educational principles are emerging amidst the digital revolution. Herold (2016) stresses the importance of creating flexible individualized learning paths, following a “competency-based progression”, focusing on mastery of a subject. These changes have the potential for students to become the creators of their own learning experience. Guardia et al. (2021) looked into strategies to maintain active learning with increased student autonomy through remote labs and mobile device apps and found that student collaboration was supported by the technology.

The National Education Technology (NETP, 2016) plan put forward a broad research-driven proposal to address the educational shift towards technology. The NETP

(2016) seeks to move towards personalized learning, where the pace and instruction are structured to meet the needs of each learner. Learning activities in the NETP (2016) are meaningful and relevant, often-times self-initiated and driven by their interests.We again see “blended” learning being a desired proposal, suggesting that a blended format will better allow for students to have some control over the pace and path of their learning. Included in this model is the potential to have larger face-to-face sessions and small groups and tutoring being held online.

The NETP further lays out the argument for incorporating technology into education - noting that technology can enable personalized learning, can organize around real-world challenges and project based learning, along with taking advantage of remote tours of out-of-school settings, and can help close the digital divide and make transformative learning opportunities available to all learners (NETP, 2016). The digital divide has traditionally been viewed as the difference in internet access across socioeconomic groups and the modernized E-rate program, originally created by Congress in 1996, supplies funding for schools to purchase high-speed internet (NETP, 2016).

One of the chosen philosophical frameworks put forward in the NETP (2016) is the Universal Design for Learning (UDL) with the aim to provide multiple means of representation of material (digital books, websites, videos, etc), multiple means for expression (writing, speeches, online media), and multiple means of engagement (games, skills, activities). NETP (2016) recommendations put forward in the plan are that states, districts and institutions should develop and implement learning resources that incorporate the flexible and dynamic nature of the internet and technological tools and do so in a manner that ensures universal access and accessibility to all students.

It seems that we are still only in the infancy of the technological revolution and truly realizing the impact that it will have on education, but the research does seem to indicate that online learning can be as - or more - effective as traditional instruction. Of course, success is not solely determined by how technically proficient and technologically modern an educator is, it is still largely based on the training and expertise (and compassion) of the educator. Solid philosophical and methodological theory still applies in the digital realm and this will be discussed in the following section.

Educational Theory

The 21st century presents new opportunities and challenges as younger generations adapt to a digitally-connected world. However advanced our technology becomes, we are still raising children with fundamentally the same capacity for human development, cognition and learning as were children in previous generations. Our great progress and discoveries in developmental psychology and educational theory is still as relevant in the classroom as ever. This section will provide the theoretical framework behind the project through an extensive literature review. It will detail the application of these principles into the project. The review will be driven by incorporating a modern and relevant, student-centered approach. The laboratory project will draw on the rich history of experiential and pragmatic learning, and more specifically, the curriculum of this project was developed using the 5E, Nature of Science, and Understanding by Design framework.

An overarching philosophy of experiential education guides all components of this project. Experiential education has been a natural ally to science education, and biology, in particular, as it lends well to laboratory and field exercises. Any analysis on experiential education would be remiss without mention of the American educational philosopher, John Dewey. Dewey was a pioneer for experiential education in the early 20th century, who argued that "all genuine education comes through experience". Dewey believed that we learn not only by "thinking", but also by "doing", and that this involves a series of continuous (and meaningful) learning experiences (Itin, 1999).

For Dewey, learning was not simply about a transmission of facts and data, but rather a preparation for the child to participate in the real-world and he believed that the goal of education was for the student to use and understand their experiences by developing the critical thinking skills necessary to examine their experiences (Itin, 1999). In this model, the student is at the center, while the teacher serves as more of a "facilitator". This "student-centered" approach towards learning rests within the learner, as they interact with the material, other students and the environment.

Experiential education has seen a resurgence in recent decades, as environmental and alternative education become more prevalent. Itin (1999) drew on the work of the Association for Experiential Education's Principles of Experiential Education and put forward the following definition of experiential education:

> Experiential education is a holistic philosophy, where carefully chosen experiences supported by reflection, critical analysis, and synthesis are structured to require the learner to take initiative, make decisions and be accountable for the results, through actively posing questions, investigating, experimenting, being

> curious, solving problems, assuming responsibility, being creative, constructing meaning, and integrating previously developed knowledge. Learners are engaged intellectually, emotionally, socially, politically, spiritually and physically in an uncertain environment where the learner may experience success, failure, adventure and risk taking. (p. 93)

This definition stresses the importance of the transactive nature of experiential education and the role that proper, formative experiences play in our development as functioning members of society. Also, this *type* of learning is the sort that can be integrated into one's personal life. Within it are the fundamental principles of experiential education: action, reflection, abstraction and application. Itin (1999) argues that as we move further into the 21st century, we will continue to need to develop citizens who actively engage in the democratic process and that experiential education is what is needed to help develop this community.

Krahenbuhl (2016) further suggests a move away from the "sage on the stage" and "passive learning environments" to a student-centered, active approach. Here, the student is the active participant in the discovery and search for knowledge, while the teacher performs various functions, including: facilitator, coach, mentor, guide, peer, referee, while providing relevant and meaningful opportunities for students to engage with.

This project will be working with two specific educational frameworks during the curriculum design - Understanding by Design (UBD) and the 5E's. UBD is an intentional approach to curriculum planning that deliberately works "backwards" from the intended knowledge and skills that the instructors want their students to gain from the activities, assessments and lessons that will reach these goals (Wiggins & Mctighe, 2011). In short, the instructors consider the learning goals first in lesson planning. Assessment is also designed well ahead of the implementation of a lesson.

Backward design encourages intentionality of planning by the instructors and gives them a framework that ensures learning outcomes are central and embedded in their planning (Wiggins & Mctighe, 2011). This also helps provide the instructor with purpose behind every task and piece of lesson design and helps instructors gauge student learning and understanding more accurately, as students must meet certain learning objectives in order to advance in the unit (Wiggins & Mctighe, 2011). Backward design has been summarized into three key "stages" which identify desired results, determine acceptable evidence and plan learning experiences and instruction.

One model of backward planning that is related to experiential, student-centered philosophy is the "5E's model", which is a learning cycle design, grounded in active learning, that stands for Engage, Explore, Explain, Elaborate and Evaluate and it is based on a constructivist theory to learning, suggesting people construct their knowledge and meaning from direct experiences (Bybee, 2015). By incorporating reflection and inquiry, the 5E model has been effective at engaging students, motivating them to learn and guiding them towards new skill development (Bybee, 2015). He goes on to suggest that educators build inquiry, exploration and assessment into their approach, where the teacher plays the role of a guiding facilitator for the students. Both backwards planning and the 5E model will be elaborated upon in further detail in the ensuing chapters.

No matter what resources an educator may have at their disposal, there is still nothing more valuable than their ability to use what they have effectively. Developing a solid educational foundation is key to one's professional development. Current research tends toward a student-centered approach across disciplines that is personalized, flexible and universally accessible. Throughout this paper an experiential, inquiry-based and student-centered approach will be drawn upon frequently. The next section will be narrowing the focus to environmental and science education and what the current research suggests are the most relevant strategies.

Environmental/Science Education

Essentially all public or private school students will encounter a series of science courses to fulfill their graduation requirements or to meet a prerequisite for further studies. For many students, they are remembered as either their hardest, most confusing subject or their most memorable and interesting. What tends to separate a quality science class from a subpar one is the amount and type of opportunities the students had to actually practice science, rather than just being fed information from text. By participating in the scientific process, students gain valuable experiential knowledge that fosters skills beyond the classroom. This section will explore the current research trends in science education and explore the best pedagogical methods. To reiterate, this paper will continue in the pursuit of an experiential, student-centered approach with the 5E learning cycle and Understanding by Design as methodological tools. Furthermore, the connection to citizen science and the importance of integrating the principles of environmental education into standards-based science teaching will be assessed.

Science, Technology, Engineering and Mathematics (STEM) programs continue to enjoy significant public and private support. The public recognizes the importance of raising a scientifically literate and innovative generation of students.Several large federal initiatives have been put forward in the 21st century to lay out a philosophical and methodological framework for teaching science, which have been explored extensively in academic research. Several key ideas seem to be consistently at the forefront: inquiry, discovery, student-centered, experiential, nature of science, and teaching how to *be* a scientist, rather than just learning a*bout* science.(Davidson & Sutherland, 2021). The National Research Council (NRC)in 2012 argued that K-12 science learning should focus on students engaging with science in ways that mirror the work of scientists.

Traditionally, 20th century American science education consisted primarily of transmitting science content being presented as factual information to be memorized for a test. However, researchers and educators recognized the need for reform in the late twentieth century, generating the concept of “science for all” - whose goal was to create a more scientifically literate society. As with any discipline, it has socioeconomic, geopolitical, financial and humanitarian interests; science is generally seen as a force of ”good” for societal progress, therefore the “cross-discipline” nature of science has been stressed in recent decades (Davidson & Sutherland, 2021).

In more recent years, the focus has been on the discipline and process of science and scientific thought itself. This can be viewed as the norms, practices, and tools of the scientific community, sociocultural contexts that influence it, the individuality and humanity of scientists, the epistemological reasoning and conceptual knowledge that scientists employ to gain an understanding of the world (Davidson & Sutherland, 2021). This gets to the fundamental essence of science; how it informs our experience of the world(García-Carmona & Acevedo-Díaz, 2018).

As García-Carmona and Acevedo-Díaz (2018) remark, there is a broad consensus amongst the international science education community that comprehension of the nature of science (NOS) should be a key element in the scientific literacy of the population. This involves learning both the necessary skills to perform laboratory and field exercises, and gaining a meta-cognitive perspective about the scientific pursuit of knowledge (objective, empirical, peer-reviewed, etc.). This includes many key principles: formulating questions, creativity, imagination, experimentation, errors as opportunity, modeling, cooperation and teamwork, along with argumentation and discussion, evaluation and communication.

Following their meta-analysis, García-Carmona and Acevedo-Díaz (2018) noted a most effective way to learn about NOS is through explicit and reflective approaches - similar to the aforementioned experiential philosophy of John Dewey. Their research suggested establishing specific learning objectives by designing lessons focused on critical thinking and aspects of NOS - which aligns well with the UBD and 5E model. NOS can also be successfully introduced through the historical narrative of science, or through confronting current societal problems, including real-world inquiry and problem solving. In general, science can be viewed as a field of human knowledge that seeks to understand the natural world, consisting of: a body of knowledge, a way of knowing and a set of processes (García-Carmona & Acevedo-Díaz, 2018). Palmer (2002) put forward a framework for teaching science through environmental education. Environmental science is a unique and important aspect of the sciences in education and we again see considerable overlap between educational disciplines.

Environmental education also grounds itself in inquiry-based, experiential learning but has an emphasis on outdoor and nature learning and on addressing environmental social causes. (Palmer, 2002). Environmental education also should encourage developing the interrelationships between learners and their environments and in this view the field should focus on the holistic development of the child as an interconnected part of their environment and society.This is generally accomplished through real-world projects, cooperation amongst a community of learners and a variety of settings (Palmer, 2002).

From a historical perspective, we see how nature, technology, science and education all share similar threads and what tends to inform one, informs the other. At the nexus of nature, technology, science and social change is citizen science, the topic of the next section. We will see how research suggests that citizen science is a powerful tool for science educators and that it naturally aligns with an experiential nature of science and inquiry-based practice.

Citizen Science

Some of the more compelling developments to come out of the field of environmental education are the many different citizen science initiatives that are available to K-12 students. A mutual relationship between academic research teams and the public has been developed that affords students the opportunity to participate in ongoing scientific studies. These initiatives are oftentimes created by universities or non-profit organizations and many of them offer curriculum to go along with participating in the study and align to particular units and subjects. This section will highlight the current landscape of citizen science in environmental and science education. It will then highlight the promising uses of technology and how that can be utilized in a virtual classroom, along with how citizen science can utilize the best features of the aforementioned educational theory.

A basic definition for citizen science (CS) is a voluntary participation of citizens in different phases of the scientific process, typically in data collection and analysis, for projects run by scientists (Aristeidou & Herodotou, 2020). Citizen Science meets a glaring need in the United States, which is that:"research has shown that the general level of understanding of basic scientific concepts and of the nature of scientific inquiry may be insufficient for the average citizen to be able to make informed decisions." (Brossard & Bonney, 2005, p. 92) As a result, efforts have been established in recent decades to support science education in not only the nation's school system, but also in promoting informal science education outside of the classroom (Brossard & Bonney, 2005). Kullenberg and Kasperowski (2016) note that citizen science was barely even visible as a discipline in the mid 1990s; however around 2010, there was a significant increase in published articles . Still, the practice of citizen science is much older, as volunteers would submit data to individual campaigns, beginning with early programs, such as the National Weather Service Cooperative Observer program in 1890 and the National Audubon Society starting its annual Christmas Bird Count in 1900 (Bonney et al., 2009).

Since the advent of digital platforms and mobile applications, citizen science has seen an explosion in popularity (Kullenberg & Kasperowski, 2016). Also, the public interest in science and environmental issues helped spur public interest in volunteer campaigns, including monitoring water quality, documenting bird distribution and breeding, identifying galaxies, collecting photos of canopy cover and many more (Bonney et al., 2009). Empirical studies in school-based settings have shown positive impacts on science learning, both on the scientific process and on the content (Aristeidou & Herodotou, 2020).

Citizen science (CS) programs have been found to be remarkably successful in advancing scientific knowledge, as volunteers contribute a vast amount of data from around the world (Bonney et al., 2009). Citizen Science initiatives generally cover long spans of time while collecting large amounts of data, allowing for research institutions to minimize cost of data collection (Kullenberg & Kasperowski, 2016). The biological sciences are where the vast majority of CS projects originate, as a method with the purpose of collecting observations in the field, oftentimes for ecological, population, or environmental studies (Kullenberg & Kasperowski, 2016). These initiatives arise from the community, as problems related to environmental, pollution, health hazards, species counts and air/water quality require datasets to help inform policy or advance a campaign around a particular issue (Kullenberg & Kasperowski, 2016). While biology tends to dominate this field, new strands of citizen research have emerged in the social sciences (humanities, geography, public health, etc) (Kullenberg & Kasperowski, 2016).

Citizen Science projects that have adopted digital platforms and mobile technologies have fared the best in terms of scientific output (Kullenberg & Kasperowski, 2016). The digital platforms generally go along with complex datasets and visualizing tools that can be used by educators to teach scientific principles (Bonney et al., 2009). They had developed a nine-point model for developing a citizen science project: 1.Choose a scientific question. 2. Form a scientist/educator/technologist/evaluator team. 3. Develop, test and refine protocols, data forms and educational support materials, 4.

Research participants, 5. Train participants, 6. Accept, edit and display data, 7. Analyze and interpret data, 8. Disseminate results, 9. Measure outcomes. (p. 979)

Aristeidou and Herodotou (2020) conducted a systematic review of effects on learning and scientific literacy and found CS initiatives to be tremendously valuable to educators. They found that CS allows for: “Learners to be viewed as self-directed individuals driven by their own personal interests and as individuals who make sense of the world through an inquiry approach to learning - that is, through manipulating, testing, observing and questioning.” (Aristeidou & Herodotou, 2020, p. 2) Technology then allows the learners to interact with each other and the content, as they also interact with their environment, while encouraging shared dialogue, group learning and ongoing interactions amongst peers. This model requires the instructor to again serve as the role of “facilitator”, helping to guide the students into the role of investigators. The facilitator also has a significant role in constructing the digital environment to serve as an effective learning space and to monitor and promote communication.

A good facilitator of a CS project should support learners through scaffolding and modeling, understanding that there will be a learning curve for new technology and digital platforms, along with the learning objectives of the curriculum (Aristeidou & Herodotou, 2020). Furthermore, this review found that technology served an essential role in the success of a CS program in a classroom, as it escalated participation and offered learning experiences of comparable quality to face-to-face education. Some projects were able to take place entirely online, allowing for people across the planet to participate together. Students were found to gain positive experiences in self-directed learning through participation in CS.

Federal agencies , such as the U.S. National Science Foundation (NSF), have put forward national programs that stress the significance of understanding and supporting citizens' learning across settings (Aristeidou & Herodotou, 2020). The trends suggest that CS is only going to continue to expand and play a larger role in K-12 settings. In light of the goals of this project, CS serves as the bridge between technology, nature, science and community action in education. For an online educator, it can be delivered completely remotely, while still providing a means to engage students in experiential, field-based and community science. The ensuing chapters will further elaborate on the specific CS initiative used for this project.

Summary

Education practitioners are responding to the unprecedented technological revolution by incorporating and adapting the historical body of knowledge in education into modern settings and technologies. Some of this has been the natural progression of technology and society and some of it has been as an emergency response to global lockdowns and school closures. Research strongly supports the notion that the best practices in face-to-face education and pen and paper also apply to digital platforms. Technology, if used effectively, can connect us to new experiences and interactive content to better reach learning objectives.

This capstone project involves creating a curriculum for a 9-12 digital classroom that is grounded in inquiry-based, experiential, and student-centered principles. Being that a biology class will serve as the example, a citizen science initiative with a digital platform and mobile application that meets current national standards will serve as the mode of delivery. CS and digital science delivery have been shown to be as effective as in-person learning, and this project will utilize the technology to fit an Understanding by Design model, which uses backwards planning, and the 5E learning cycle model, based around discovery and the scientific process.

Research is clear that education in the 21st century will require a shift away from teaching science as merely a transmission of information and facts, to an approach that favors direct experience, real-world challenges, local and international communities and the discipline of science itself. This project seeks to find the intersection of these principles, with the vision of delivering quality science experiences over completely digital means, while taking part in meaningful and socially-important science initiatives.

The following chapter discusses the methods of this implementation and expands on the materials that have been selected for design. The primary framework that will be discussed will be a curriculum development from the University of Minnesota and the National Phenology Network called “Nature's Notebook” , that invites students to record phenological observations of various species in nature, which contributes to a massive dataset that can be visualized by sophisticated graphing software (Thompson et al., 2018). The method section will further describe the selection and implementation of the various tools and software to be used.

CHAPTER THREE

Methods

Introduction

This paper and capstone project seeks to find a practical solution to the current paradigm shift in K-12 education - that of an ever-increasing emphasis on technology and digital life, paradoxically making us more connected and more isolated at the same time. This evolution seems inevitable and it would be wise, as an educator, to embrace this change and find a set of tools, skills and theory to be able to best serve your students. This chapter will put forward a solution to this paradigm by answering the question: "*Can outdoor, experiential education be successfully integrated into modern science classrooms?"*

Throughout the construction of this project, an inquiry-based, experiential and student-centered philosophy and framework will be adhered to. This will be accomplished by preparing the curriculum within the Understanding by Design (UBD) and 5E's Learning Cycle (5E's) frameworks, which both identify learning objectives before designing relevant activities and material that will demonstrate student achievement. The 5E's further incorporates a learning cycle that ensures active discovery, exploration and critical thinking are embedded into the investigation. By using these models and applying them to a Citizen Science (CS) phenology initiative, this project will produce a formative laboratory experience that aligns with Next Generation Science Standards (NGSS).

The University of Minnesota's Driven to Discover program (D2D), in partnership with the USA National Phenology Network (NPN), have created the Nature's Notebook

CS initiative, which involves thousands of volunteers collecting data on seasonal variation amongst plant and animal species (Thompson et al., 2018). This is one of the larger CS campaigns, with an impressive dataset that tracks observations from over a century ago. Through a mobile application called "Nature's Notebook", students can record observations remotely and later visualize the data on the NPN website. This partnership, along with many independent educators, has created a curriculum for K-12 educators to achieve various learning objectives through participating in the program. There are a number of lesson and unit plans, planning guides, and other educator resources listed in a convenient database on their website. This project serves to adapt the material to a classroom with access to the Minnesota Valley National Wildlife Refuge (MVNWR) in Bloomington, MN. This chapter will highlight the methodology in designing and assembling the curriculum resource. Furthermore, this outline should serve as evidence for the utility and relevance of the project as a whole.

Project Design

At the core of this project is a student-centered, experiential philosophy of education. This will be demonstrated in this methodology and selection of lesson materials and planning. Learning objectives will be identified and reached by adhering to an Understanding by Design (UBD) and the 5E's learning cycle, which stresses discovery, cooperation, inquiry, experience and reflection - all essential features of holistic, student-centered, experiential education. Students will engage in the Nature of Science (NOS) and familiarize themselves with the scientific process. Furthermore, this project will develop students' digital and technical skills, as they navigate and engage with an online platform and mobile application. The end product will involve a unit of study that culminates with a laboratory project that includes assessment, instruction, data collection and field research. The delivery of the lessons and all interactions will have to be done through the digital space via an online classroom and mobile application.

The UBD model intentionally works backwards to achieve the pre-determined learning goals and is broken up into three key stages 1. identify desired results, 2. determine acceptable evidence and 3. plan learning experiences and instruction (Wiggins & Mctighe, 2011). The 5E's learning cycle of "Engage, Explore, Explain, Elaborate, and Evaluate" provide a framework for science and environmental education to plan experiential lessons. This coincides with the basic scientific process of: asking questions, making observations, constructing a hypothesis, testing the hypothesis, analyzing the data, drawing conclusions and returning to the hypothesis and reporting. This experiential, scientific approach has been effective at motivating and engaging students and encourages inquiry and exploration (Bybee, 2015). Within these frameworks, the teacher should assume the role of the "facilitator" or the "manager" or "coordinator". A lot of initial preparatory work is required of the instructor to set up the laboratory project, however. But once the unit commences, the instructor should help guide students toward their own inquiry and discovery and help with troubleshooting and brainstorming.

The D2D Classroom Phenology Guide (Thompson et al., 2018) provides a framework for a "condensed" sequence of a phenology program for a secondary class that covers 10 periods over the course of three weeks. This includes four "phases": 1. preparation, 2. build science skills, 3. contribute to citizen science, and 4. conduct investigations (Thompson et al., 2018). Within the guide are several lessons to choose from and various "mini-investigations". What is particularly compelling about this initiative is that the NPN has collected a substantial amount of data over decades for many different species and regions. This data is then accessible through their sophisticated visualization and graphing tools, including overlaying with meteorological and climatic data. This feature of data over time and space provides endless scientific curiosity for students and educators. Furthermore, many of the data collection campaigns have cultural and regional significance, and a subsequent historical perspective to explore. Within the D2D literature, there is a particular lesson that I will be adapting, which is called “Science Behind the Scenes: Phenological Changes Reflect Climate Change in Wisconsin” and it presents a famous historical case study of phenological data of migratory birds. This involves analyzing data, interpreting graphs, and discussing scientific concepts (Thompson et al., 2018). This lesson will also help students conceptualize the practice of science and how their investigation relates to the real-world.

Other lessons will be adapted and included which teach NOS principles such as making observations, asking questions and formulating and testing hypotheses. One of these is a necessary primer on making phenological observations and how to collect and report this data within Nature’s Notebook. This will provide necessary modeling and scaffolding to familiarize the students with the platform, datasheets and basic process. A similar lesson will familiarize students with mystery plant identification and the use of field guides to make accurate scientific observations. These lessons will provide the necessary “tools” to conduct an independent investigation.

The bulk of the project will involve the independent investigation conducted by the students. Here, they will be grouped into small teams of 3-4 and will be required to set up a Nature’s Notebook account, along with downloading the mobile application.

Next, students will be given a “Build a Scientific Explanation Worksheet”, which uses a format for developing a scientific explanation that is broken down into: evidence, claim and reasoning - in that order. Students will also utilize an “I Wonder Board” as their investigations are ongoing (Thompson et al., 2018). As the investigation progresses, teams learn to ask questions and they formulate a hypothesis. Meanwhile, they are learning laboratory skills as they identify plant and animal species using field guides and study the morphological timing of their seasonal change. Students will take photos and share their research in online forums as they construct their project for a formative assessment, which culminates in a “digital symposium” where student teams present their findings in the form of a digital slideshow or video.

Setting and Audience

This project will be designed to be carried out to either a traditional or hybrid high school life science class. While the specific focus of the paper is to reach a U.S. public school, 9-12 online classroom, this curriculum could also be used with charter schools, homeschool groups, nature centers or any individual or organization that shares similar citizen science and environmental educational goals. This curriculum would work well for either small groups (3 to 7 students) or full-sized classrooms (30-40 students). For the sake of clarity, I have chosen the representative class to be a 10th grade public school class of 20 students in a core life science class. This could be delivered to students living in an urban, suburban or rural setting. Students will be expected to conduct species observations outside on a semi-regular basis. Furthermore, this paper will assume a situation where all of the students will have regular access to a mobile phone/tablet, a computer and the internet (which is provided by MVNWR). This project also requires that students have safe and easy access to a natural setting (yard, park, school grounds, etc) where they locate species to observe.

This curriculum will split work between on-site “in the field” work and analysis and reflection in the classroom. This will provide the instruction and facilitate communication between the students and the instructor. The classroom space will offer a venue to build community by sharing ideas, findings, photos and videos. This will also be the “hub” for the other parts of the project, including data collection, analysis and visualization through the Nature’s Notebook website and mobile application. Lastly, this project’s setting involves the student and the instructor’s own physical home office space.

Included in the setting and audience would be the positionality of the author. I was raised in a rural Minnesota town, by middle class, married parents who were both college educated. Education was always emphasized in my youth and it was this early encouragement and support that brought me here today. As a single professional adult and current graduate student, I see myself as just another learner helping other learners in the reciprocal school of life. My desire is that I’ll be able to provide the same support, encouragement and opportunities to future generations, regardless of their demographic profile. The intended product of this project is designed to be versatile and flexible to meet students where they are at, using common tools and tapping into their natural curiosity.

Timeline

It will require some time to be fully ready to implement. First, the digital classroom space needs to be constructed. It needs to have a space for sharing presentations, for accessing material, for communicating and for tracking student progress. There will be additional digital content that will be included to explore the potential of virtual learning. Fortunately, the USA National Phenology Network (NPN) and University of Minnesota have already created a substantial amount of material related to this project, although it will need to be adapted for delivery and specific aims of the schools in partnership with the MVNWR. Altogether, it will likely take several weeks to have the curriculum guide designed and functional to carry out the unit.

These methods take the perspective of a teacher setting up a phenology lab for the first time. This involves some work upfront, including identifying appropriate species, locating datasets, creating graphic representations, and setting up the mobile application accounts. The laboratory project itself will cover approximately ten, one-hour class periods and will require independent work from both the instructor and students. Altogether, with the introductory lessons, laboratory project and assessment/presentation of the project, this paper will detail 15, one-hour class periods. Being that phenology is a subject which topically aligns best with ecology, this will be taught during a six-week ecology unit in the fall or spring semester, as phenology is best observed during seasons of dramatic temperature and light change. Lastly, considerations for grading, troubleshooting and adaptation will be included in planning.

Assessment

Students are expected to demonstrate the scientific process and to practice being a scientist. They are also expected to be good citizens and members of their community and environment. This is the focus of this work - to create a learning experience that develops the learner in a holistic manner. Some of the benefits of interacting with nature and fellow people that this project involves are intangible and not easily assessed, but an educator *can* measure the level of student engagement and meeting learning outcomes to better inform their practice. This involves formative and summative assessments and teacher reflection.

For the formative assessment, students will take part in a “digital symposium” to showcase their work. Students will be asked to create a series of slides or a video presentation, replicating the experience of scientists when presenting their research findings at a scientific conference. A rubric will be provided that measures learning objectives, including: measuring the students’ ability to collect, analyze and represent data, the students’ ability to demonstrate the scientific process and the nature of science (NOS), along with their ability to communicate and contribute to a team.

Summative assessment will focus on demonstrating student understanding of the concepts, terminology and ecology learning objectives. These will take the form of online quizzes, surveys, short answers and class discussions online. These assessments will be embedded into the online classroom and will provide data to better inform future instruction. Lastly, like any good experiential lesson, teacher reflection will be included at the conclusion of the project to encourage improving pedagogical practices.

Summary

In creating this project, I hope to not only have this curriculum ready to use in my own classroom, but also will gain a versatile method of adapting an ordinary secondary science unit into something formative and meaningful that is not only tapping into new technological developments, but is also grounded in trusted experiential and student-centered philosophy. There are countless CS initiatives and digital platforms that could be integrated into a classroom and the 5E learning cycle, UBD and Evidence-Claim-Reasoning can be applied to any investigation.

This curriculum guide will integrate the instruction, assessment and grading all into one resource for a teacher. This guide will provide a framework for carrying out a number of lessons, laboratories and connecting the class to science and the community. This then becomes a powerful tool-kit to possess as an educator which is useful in any modern educational or academic setting. Most importantly, this project should provide a meaningful and memorable experience for students, which imparts them with real-world skills and a greater understanding of scientific thinking and science as a discipline.

\

CHAPTER FOUR

Conclusion

Introduction

As educators, our reach and connectedness are advancing exponentially. With a viral hit, one can reach audiences in the millions through their devices almost instantaneously. Furthermore, the internet is full of world-class resources, simulations, modules and assessments for teachers and students at our fingertips. The "Information Age" has produced nearly an infinite amount of information to consume, but have we paused to reflect on the quality and substance of these connections? Perhaps we shouldn't abandon nature and lived experience too quickly, lest we forget what makes us whole. That is the essence of what was explored in this project, which asks the question: "*Can outdoor, experiential education be successfully integrated into modern science classrooms"*

As discussed at length previously, experience and nature can be powerful tools in the science classroom - they promote curiosity and engagement and offer lasting and meaningful memories. This has been the hope of this capstone project and this chapter will review how the outcome compares to the initial aspirations. In a sense, this is an experiential report about creating an experiential science program - a testing of a hypothesis and reporting of the results. This overview critically examines the project in three parts: 1.) How was the project created? 2.) How well was the research question addressed? and 3.) Reflecting on the experience and looking towards the future.

By revisiting the literature review and analyzing the project against best educational practices, it becomes clear that a phenology teaching program would be an excellent tool for a science educator in the 21st century to use. While the catalog of curriculum in the handbook hasn't all been tested in the classroom at the time of this publication, we can still propose ways that a versatile teacher could integrate this into a standardized ecology unit. In the following sections, several ways to implement and expand on this work are addressed, along with a reflection of this project as a model for similar ventures.

Creating the Phenology Teaching Handbook

I became an environmental educator intern at the Minnesota Valley National Wildlife Refuge (MVNWR) in the winter of 2016 and was initially tasked with helping to set up a three-part phenology trail to serve as a teaching resource for area schools. I knew nothing about phenology and little about environmental education, but the challenge intrigued me. My supervisor quickly briefed me on what goals she had for the program and introduced me to other educators who were helping - biologists and rangers from the U.S. Fish and Wildlife Service, a teacher from Belwin Conservancy, outreach educators from the University of Minnesota and contacts at the U,S. National Phenology Network (USA-NPN) and Minnesota Phenology Network (MPN).

With the expert guidance of on-site biologists and an experienced environmental educator, we chose species along the refuge that were relevant to the greater scientific community and also accessible along a set of three trails. I then spent the next several months putting together graphics, placards, maps and posters to prepare for a public launching of the Refuge Phenology Trail. It was decided that we would host a “Phenology Workshop" for volunteers and interested members of the public at the MVNWR visitor center. Researchers from the University of Minnesota were brought in to present on the history and science of phenology and I gave a tour of the trail and overview of the resources that the refuge would provide. We even had a student art contest to help design the poster for the trail. We immediately saw eager adult volunteers making regular observations on the trail's species.

While the refuge was able to have some success with collecting phenological data for the USA-NPN and "Nature's Notebook", the initial aim of providing the trail as a teaching resource was left unfinished. The USA-NPN had already created and collected a fair amount of quality lesson plans and teaching resources, but it became clear that it was not simplified enough for an educator to quickly pick up and use in their classroom. In this state, the MVNWR Phenology Trail teaching program required a significant amount of training to familiarize a teacher with the resources available. As a result, the trail remained more of a volunteer data collection opportunity that was largely done by staff or dedicated volunteers.

One of the exciting aspects of providing curriculum for the MVNWR is that they have been partnering with school districts in the Twin Cities metro for many years already - providing semi-regular educational field trips to the refuge and lessons brought into classrooms with many area teachers, even arranging the bus transportation. The visitor centers are equipped with classrooms, projectors, computers, iPads, outdoor clothing, and seemingly any environmental education teaching tool that exists. They also have a large team of biologists, rangers, and expert volunteers working on site. This is a somewhat unique program in the country, with such a strong partnership and refuge specific K-6 curriculum. The infrastructure was in place, but an accessible guide hadn't been put together to attract high school and middle school science teachers, yet.

Following the internship, I continued with student teaching and a variety of different employment opportunities and, after a hiatus from graduate school, I decided to finish my capstone project. It was at this time that the aforementioned pandemic swept the globe and schools abruptly had to deliver online lessons. Students were largely limited to learning material through their digital screens in their rooms. The isolation and fear brought upon from the pandemic took a noticeable toll on the mental, social and physical health of the youngest generation. As I pondered this unprecedented situation, I set about to identify a research question, and I was brought back to the unfinished "Phenology Trail Teaching Handbook", seeing this as an opportunity for students to create meaningful connections and experiences out in the "real world" again.

Addressing the Research Question

In order to answer the question: "*Can outdoor, experiential education be successfully integrated into modern science classrooms?"* - a few parameters had to be defined. Such as: What type of outdoor, experiential education? What is a modern science classroom? And - what does successful integration look like? The question was intentionally left somewhat broad, as this process of creating an "experiential handbook" could be applied to any number of projects and studies.

One of the challenges of this project was narrowing down these very broad ideas into something tangible that serves a specific role. An end-product was immediately clear. To solve this, the advice of many individuals were sought, from the teaching team at the MVNWR, to the education specialists at the USA-NPN and with 9-12 science content experts. It was agreed that a MVNWR-specific "Phenology Trail Teaching Handbook" would be the most impactful and relevant product to create.

As for “successful integration” - this involved gaining an understanding of the current trends in educational research and philosophy. There is a growing interest in bridging the gap between the digital and real-world in education, seeing how technology serves an ever greater presence in our daily lives. This coincides with a growing appreciation for experiential, relevant and place-based learning. Of particular emphasis in this project is learning science by practicing and *being a scientist,* rather than merely learning through a textbook or screen (Davidson & Sutherland, 2021).

A practice that applies both the real-world, experiential principles and the scientific method is the 5E Learning Model consisting of: engage, explore, explain, extend, and evaluate(Thompson et al., 2018). This model is frequently integrated into the MVNWR Phenology Trail lesson plans, along with the similar model of “Claim - Evidence - Reasoning” (CER) and “What I know Know - Want to Know - What I Learned” (KWL) models. In the 5E model, students engage by asking questions to help generate interest and focus on observation and details in nature, while connecting with past experiences. Students then explore the ideas of physical materials before explaining the content and concepts. After explaining, students elaborate using broad questions to encourage reasoning, analysis and problem-solving. Lastly, students are evaluated by observing them as they apply new concepts and skills. Within the 5E lesson template provided for teachers in this handbook are ways to connect to standards, learning objectives and the community. Teachers are also provided with the logistics, materials and time required to perform these lessons and a space for teacher reflection following the lessons.

The MVNWR Phenology Trail Teaching Handbook contains several lessons based around the 5E educational model, along with an example unit overview for teachers to consider. Within the handbook are several guides for collecting data, making observations, along with instructions on how to use and visualize the data to conduct scientific investigations. These lessons all come equipped with specific learning objectives and Next Generation Science Standards (NGSS) and cross-cutting concepts associated with them. Furthermore, the PDF version of the handbook contains hyperlinks throughout its 72 pages of information. This allows the user to quickly access the full and official resources and publications from the USA-NPN. The handbook therefore provides a simplified guide for a specific audience (middle and secondary science teachers). The education team at USA-NPN graciously provided a collection of middle to high school phenology lesson plans and resources for adaptation in this project.

Now - at the MVNWR visitor center - an area teacher could bring their high school class on an arranged bus ride, where they could pass out refuge-provided iPads set-up to collect data for Nature's Notebook. Teachers could receive a welcome and initial instruction from refuge staff and a classroom to themselves. The teacher, with some prior familiarization, could then lead the class on a scenic hike, stopping at species' observation points to record findings. Then, the teacher could return to the classroom and follow-up with visual investigations into the data that link their learning into a number of pre-designed lessons. The teacher leaves with instructions for setting up a similar monitoring program at their school. The final result being a model for successful integration of outdoor, experiential education into a modern science classroom.

Reflection and Projection

At the very least, there is a sense of relief in tying together various loose-ends and finishing an unfinished project. At the conclusion of the creation of this handbook, it has yet to be tested in action or subjected to academic scrutiny, but there can be some confidence in the quality of the product because of the trusted and reliable frameworks that went into creating it. Developmental and educational research has shown us the importance of student-centered, real-world and experiential learning(Davidson & Sutherland, 2021). The best practices of science education inform us not only to present vocabulary terms and concepts, but to have students gain an understanding of the scientific process and community and learn how scientists investigate and answer questions. To then present this information in a way that builds upon prior learning and extends to future applications is where models such as CER, KWL and the 5E's become versatile, yet simple tools to use in inquiry.

The logical next investigation would be to put the entire handbook, trail and science class into action. The planned "stopping point" of this phase of the project was to be able to hand the teaching handbook off to a prospective 6-12 science teacher who could fairly easily integrate this into a biology (ecology) unit while committing to a rewarding partnership with the academic, scientific and natural resource communities. An objective case study of using the trail and handbook with a class would be a valuable area of future study. There is a great deal of intentional variability in terms of how a teacher might implement this and evaluate the results - the idea was to leave a good deal of choice and variety and blank templates for a teacher to use, without needing to follow a fixed set of steps.

One objective of this paper and accompanying project was to gain a greater level of practical and theoretical experience in developing curriculum and teaching programs. The methodology in creating this handbook could be applied to any number of pursuits. One of the drawbacks of the "information age" with education is that there's an intimidating overload of information, initiatives, websites, projects and resources available. This material is oftentimes generalized to a broader audience, rather than designed for a more specific subset. What this project was successful in doing was filtering through a vast amount of information and condensing it down to a functional level - taking a more generalized set of curriculum and adapting it to a local and "placed-based" audience, which increases relevance and meaning for the learner.

Conclusion

We can only hypothesize how younger generations will interact with and experience the world. Someone raised a hundred years ago would hardly recognize today's world. This rate of change only appears to be increasing exponentially. Surely, our dependence on technology will only increase in the coming years - especially in education - which has undergone more change in recent years than ever before.

Finding a healthy balance between our digital and natural lives ought to be of utmost importance for those entrusted with raising future generations. Information has proliferated our world, but have we preserved a place for wisdom, relationship, understanding and experience in the growth of a child? Perhaps this journey of creating experiences and learning about learning can provide a spark of insight into this brave new world.

REFERENCE LIST

Abrami, P. C., Bernard, R. M., Bures, E. M., Borokhovski, E., & Tamim, R. M. (2012). Interaction in distance education and online learning: Using evidence and theory to improve practice. *The next generation of distance education* (pp. 49-69). Springer, Boston, MA.

Analytics Insight. (2020, September). *Top Digital Transformation Trends in Education Post Covid-19* https://www.analyticsinsight.net/top-digital-transformation-trends-education-post-covid-19/

Aristeidou, M. & Herodotou, C. (2020). Online Citizen Science: A Systematic Review of Effects on Learning and Scientific Literacy. *Citizen Science: Theory and Practice*, *5*(1), 11. DOI: http://doi.org/10.5334/cstp.224

Bates, A.W. (2019). *Teaching in a Digital Age – Second Edition*. Vancouver, B.C.: Tony Bates Associates Ltd. https://pressbooks.bccampus.ca/teachinginadigitalagev2/

Bolliger, D. U. & Martin, F. (2018). Instructor and student perceptions of online student engagement strategies. *Distance Education*, *39*(4), 568–583. https://doi.org/10.1080/01587919.2018.1520041

Bonney, Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *Bioscience*, *59*(11), 977–984. https://doi.org/10.1525/bio.2009.59.11.9

Brossard, L., B., & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education*, *27*(9), 1099–1121. https://doi.org/10.1080/09500690500069483

Bybee, R. (2015). *The bscs 5e instructional model: Creating teachable moments*. National Science Teachers Association. ProQuest Ebook Central, https://ebookcentral.proquest.com/lib/hamline/detail.action?docID=5254062.

Center for Implementing Technology in Education. (2016, June), "Lessons Learned for Effective Technology Implementation." http://www.cited.org/index.aspx?page_id=206.

Davidson, J., L. Z., & Southerland, S. A. (2021). Cultivating Science Teachers' Understandings of Science as a Discipline. *Science & Education*, 1–27. https://doi.org/10.1007/s11191-021-00276-1

DiPietro, M. (2008). Best practices in teaching K-12 online: Lessons learned from Michigan Virtual School teachers. *Journal of Interactive Online Learning.*, *7*(1), 10–38

Education Week. (2020, May 15). *Coronavirus and school closures.* https://www.edweek.org/ew/section/multimedia/map-coronavirus-and-school-closures.html

Eggleston, C., & Fields, J. (2021). Census Bureau's Household Pulse Survey Shows Significant Increase in Homeschooling Rates in Fall 2020. *US Census Bureau*.

Estes, C. A. (2004). Promoting Student-Centered Learning in Experiential Education. *The Journal of Experiential Education*, *27*(2), 141–160. https://doi.org/10.1177/105382590402700203

García-Carmona, & Acevedo-Díaz, J. A. (2018). The Nature of Scientific Practice and Science Education: Rationale of a Set of Essential Pedagogical Principles. *Science & Education*, *27*(5-6), 435–455. https://doi.org/10.1007/s11191-018-9984-9

Gasevic, D. (2020, April 26). COVID-19: The steep learning curve for online education. LENS.https://lens.monash.edu/@education/2020/04/26/1380195/covid-19-the-steep-learning-curve-for-online-education

Guàrdia, L., Clougher, D., Anderson, T., & Maina, M. (2021). IDEAS for transforming higher education: an overview of ongoing trends and challenges. *International Review of Research in Open and Distributed Learning*, *22*(2), 166-184. https://doi.org/10.19173/irrodl.v22i2.5206

Harris, Dixon, C. G. H., Bird, E. B., & Ballard, H. L. (2020). For Science and Self: Youth Interactions with Data in Community and Citizen Science. *The Journal of the Learning Sciences*, *29*(2), 224–263. https://doi.org/10.1080/10508406.2019.1693379

Herold, B. (2016, June 7). Technology in Education: An Overview. *Education Week*. Editorial Projects In Education. http://www.edweek.org/ew/issues/technology-in-education/

Herold, B. (2016, February 5). Technology in Education An Overview. *Education Week.* https://www.edweek.org/technology/technology-in-education-an-overview/2016/02

Itin, C. M. (1999). Reasserting the Philosophy of Experiential Education as a Vehicle for Change in the 21st Century. *The Journal of Experiential Education*, *22*(2), 91–98. https://doi.org/10.1177/105382599902200206

Keser, H., and Ali, S. (2019). Technology trends, Education 4.0 and beyond. *Contemporary Educational Researches Journal* 9.3 : 39-49.https://doi.org/10.18844/cerj.v9i3.4269

Kocdar, S. (2017). Designing Teaching and Learning for a Digital Age. *The International Review of Research in Open and Distributed Learning*, *18*(3). https://doi.org/10.19173/irrodl.v18i3.3107

Kokotsaki, M. & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Krahenbuhl, K. S. (2016). Student-centered Education and Constructivism: Challenges, Concerns, and Clarity for Teachers. *The Clearing House*, *89*(3), 97–105. https://doi.org/10.1080/00098655.2016.1191311

Kullenberg, C. & Kasperowski, D. (2016). What Is Citizen Science?--A Scientometric Meta-Analysis. *PloS One*, *11*(1), e0147152–e0147152. https://doi.org/10.1371/journal.pone.0147152

Mayer, R. E. (2019). Thirty years of research on online learning. *Applied Cognitive Psychology*, *33*(2), 152–159. https://doi.org/10.1002/acp.3482

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies. https://www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf

National Education Technology Plan. (2016, June). *Office of Educational Technology*. http://tech.ed.gov/netp/.

National Research Council. (2015). Guide to Implementing the Next Generation Science Standards. Washington, DC: The National Academies Press. doi: 10.17226/18802.

NGSS. (2013). *Next generation science standards : For states, by states*. National Academies Press. https://doi.org/10.17226/18290

Palmer, J. (2002). *Environmental education in the 21st century: Theory, practice, progress and promise*. Routledge.https://search-ebscohost-com.ezproxy.hamline.edu/login.aspx?direct=true&db=nlebk&AN=76519.

Palvia, S., Aeron, P., Gupta, P., Mahapatra, D., Parida, R., Rosner, R., & Sindhi, S. (2018). Online education: Worldwide status, challenges, trends, and implications. *Journal of Global Information Technology Management*, *21*(4), 233-241. https://doi.org/10.1080/1097198X.2018.1542262

Pew Research Center. (2020, September). *The Internet and the Pandemic* https://www.pewresearch.org/internet/2021/09/01/the-internet-and-the-pandemic/

Rickinson, M. (2001). Learners and Learning in Environmental Education: A critical review of the evidence. *Environmental Education Research*, *7*(3), 207–320. https://doi.org/10.1080/13504620120065230

Schleicher, A. (2020). The impact of COVID-19 on education: Insights from education at a glance 2020. *https://www.Oecd.org/education/the-impact-of-covid-19-on-education-insights-education-at-a-glance-2020.Pdf.*

Smith, B., & Mader, J. (2016). Science 2.0: Transforming Science Education With New Tech Standards. *The Science Teacher (National Science Teachers Association)*, *83*(6), 8–8. http://www.jstor.org/stable/44160002.

Thompson, A; Strauss, A. L.; Oberhauser, K. S.; Kooman, M. H.; Montgomery, R.; Andicoechea, J.; Blair, R. B. (2018). Driven to Discover Citizen Science Curriculum Guide: Phenology and Nature's Notebook. University of Minnesota Extension. Retrieved from the University of Minnesota Digital Conservancy, https://hdl.handle.net/11299/198624

U.S. Department of Education, National Center for Education Statistics. (2020, June 3). *Fast facts: Back to school statistics (372)*. https://nces.ed.gov/fastfacts/display.asp?id=372

Van Schoors, R., Elen, J., Raes, A., & Depaepe, F. (2021). An overview of 25 years of research on digital personalised learning in primary and secondary education: A systematic review of conceptual and methodological trends. *British Journal of Educational Technology*, *52*(5), 1798-1822.

Wiggins, G., and McTighe, J. (2011).. *The Understanding by Design Guide to Creating High-Quality Units*, Association for Supervision & Curriculum Development. https://ebookcentral.proquest.com/lib/hamline/detail.action?docID=698904.

World Economic Forum. (2020). The COVID-19 pandemic has changed education forever. *Global Agenda*. https://www.weforum.org/agenda/2020/04/coronavirus-education-global-covid19-online-digital-learning/