Spring 2018

Exploring Multi-Sensory Curriculum Development: Grades 3-5 Science In A Virtual Environment

TeriLynn Stackhouse
Hamline University

EXPLORING MULTI-SENSORY CURRICULUM DEVELOPMENT:

GRADES 3-5 SCIENCE IN A VIRTUAL ENVIRONMENT

by

TeriLynn S. Stackhouse

A Capstone Thesis submitted in partial fulfillment of the requirements

for the degree of Master of Arts in Education:

Natural Science and Environmental Education

Hamline University, Saint Paul, MN

April 2018

Primary Advisor: Dr. Vivian Johnson
Secondary Advisor - Expert Reader: Laura Houser
Peer Reader: Will Stackhouse

ACKNOWLEDGEMENTS

The author wishes to thank her family for their tenacity and patience during the Capstone Thesis writing project. It is finally accomplished, the author being a caregiver and full-time worker, and having overcome with several family members their diagnoses and subsequent health challenges.

The author gives thanks to her daughter Linnéa Forbes for her encouragement throughout the last two years. May your studies in Marine and Aquatic Biology be exciting! The author particularly wants to commend her husband, Will Stackhouse, who also completed his own Capstone Project during this spring semester so that we could graduate together with Masters' in Education degrees. Congratulations, dear Will!

Thanks to my expert reader, Laura Houser, a science educator and school administrator, for clarity and challenge in the editing process; and to Dr. Vivian Johnson for her expertise in leading this author forward through the permutations of thesis writing.

To stimulate life,—leaving it then free to develop, to unfold,—herein lies the first task of the educator. In such a delicate task, a great art must suggest the moment, and limit the intervention, in order that we shall arouse no perturbation, cause no deviation, but rather that we shall help the soul which is coming into the fullness of life, and which shall live from its own forces. This art must accompany the scientific method.

When the teacher shall have touched, in this way, soul for soul, each one of her pupils, awakening and inspiring the life within them as if she were an invisible spirit, she will then possess each soul, and a sign, a single word from her shall suffice; for each one will feel her in a living and vital way, will recognize her and will listen to her. There will come a day when the directress herself shall be filled with wonder to see that all the children obey her with gentleness and affection, not only ready, but intent, at a sign from her. They will look toward her who has made them live, and will hope and desire to receive from her, new life.

~ Montessori, M. (1912/1964, p. 116)

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER ONE - INTRODUCTION AND RESEARCH QUESTION

Overview of Chapter

The question "What are virtual tools and multi-sensory strategies that can be integrated into curriculum development to support the engagement of learners in science in grades 3-5 in virtual learning environments?" is one that is close to my heart as since 2015 on a daily basis I work with students in a virtual school as a family support liaison. As an educator with a science specialty on my substitute teaching license my professional experience supports the idea that the development of multi-sensory approaches embodying the nine intelligences (Gardner, 1999) could be a powerful tool to enrich the study of the science. For the remainder of this capstone the school where this curriculum will be used is referred to as Engaging Virtual Academy (EVA), a pseudonym for my school, to protect the confidentiality of my participants.

My work at EVA consists of supporting students in grades 3-5, assisting the students and their families to engage or to re-engage in the online school. In my role, I work with students as they are getting started in the school for the first time as online learners. I also teach students and their parents/learning coaches how to use the K-5 and 6-12 learning management systems, how to develop good habits in the virtual learning environment, and how to learn effectively in the online school. Additionally, later if students become less engaged or their grades fall, I am called upon by teachers to take referrals, assigned by our lead, to help learners get back on track in their schoolwork.

At EVA, the software includes the use of Blackboard Collaborate live sessions, and EVA curriculum that involves books, materials and online lessons. The EVA curriculum itself uses various approaches – both online and hands-on – to help students complete their schoolwork.

The lessons are interactive and involve the use of all the senses as the students do their work. EVA also uses other software programs for reading improvement, mathematics support, Study Island, and platforms to teach foreign language and music.

Capstone Goal

The goal of this project is to explore, to find, and to apply multi-sensory strategies and teaching approaches to develop a new curriculum unit using new technologies available to enhance and enrich the virtual lesson process. A major objective of this unit is to enhance the learning experience, which may help prevent students from getting off track and becoming part of our referral system.

Many of the students with whom I work have the most trouble with successful completion of lessons in mathematics and sciences. This author is aware that sometimes science, technology, engineering and mathematics (STEM) topics can be difficult or discouraging to some students. In discovering and applying new multi-sensory strategies, my goal is to present science in such a way that it captures their attention and energizes their minds, by taking traditional educational strategies and translating their use into the world of virtual education. A deeply held professional value is that using multi-sensory approaches to re-engaging a student in learning could be a powerful way to find a vibrant interest or exciting perspective that they have not had before.

In this project, I will review John Dewey, Maria Montessori, and Howard Gardner who have all addressed the need for multi-sensory instruction to help students learn more effectively. Successful multi-sensory education and experiential educational techniques have been undertaken for decades by these authors, but can be expanded and enriched by the study of virtual reality, mixed reality, virtual technology, and the neurosciences, and implemented in the

virtual environment. I will then share a curriculum unit, taught in the virtual environment that would be likely to enrich the educational process for virtual learners at EVA. The unit may be effective for new students, or those who are re-engaging after having been off track in their educational processes.

Significance of the Capstone Research

This study is significant because it empowers students to learn using virtual reality, mixed reality, and virtual technology that supplement current traditional classroom techniques and that enhance education. Using technologies that enhance the multi-sensory possibilities for education has the potential to create an example of a new curriculum approach for programs for science in the elementary grades. By integrating the use of these technological tools, which are currently lacking in traditional classroom or virtual education, this research provides avenues for enlivening curriculum using virtual tools. These tools are currently available but largely unused at present. Teachers may increase their use of these tools if they see an example of how it is possible to provide enriching multi-sensory experience, experiential learning cycles, and learning opportunities using these technologies in multiple dimensions for both traditional and virtual classrooms.

Conclusion

To summarize, my aim is to use virtual technologies to discover new multi-sensory strategies for education, and how a teacher can transfer multi-sensory approaches to learning into the virtual world, to provide engagement for children inside the virtual classroom. In this paper the author will work toward using the virtual tools and the offline materials for a comprehensive approach that uses Gardner's (1999) nine intelligences, Dewey's (1938/1997) experiential learning cycles, and Montessori's (1912) sensory rich methodology. Virtual education and

hands-on, tactile experiences will be explored, combined, and envisioned for best practices. Chapter Two is a summary of big ideas and strategies identified during review of the research literature for this capstone. Chapter Three describes the how the curriculum was developed. Chapter Four presents the newly developed curriculum unit and Chapter Five is a reflection on what the author learned during the capstone process, of how the author views herself as a researcher/scholar at the end of the process, and recommendations for future research.

CHAPTER TWO - LITERATURE REVIEW

Howard Gardner and Multiple Intelligences Theory

The target question: The question "What are virtual tools and multi-sensory strategies that can be integrated into curriculum development to support the engagement of learners in science in grades 3-5 in virtual learning environments?" invokes first the exploration of multiple intelligences. Howard Gardner, a psychologist and professor of neuropsychology, introduced the concepts of different ways of approaching the world, or multiple intelligences. According to Gardner's (1999) theory, an "'intelligence' encompasses the ability to create and solve problems, create products or provide services that are valued within a culture or society" (p. 41). Listed below are key points of Gardner's theory (1999):

- All human beings possess all nine intelligences in varying degrees.
- Each individual has a different intelligence profile (the predominant way or ways he or she learns and processes information).
- Education can be improved by assessment of students' intelligence profiles and designing activities accordingly.
- Each intelligence occupies a different area of the brain's structure and therefore exercises different connections in the brain.
- The nine intelligences may operate in concert or independently from one another.
- These nine intelligences may define the human species.

This theory was first proposed in 1983 with Gardner's book "Frames of Mind." This first volume led to expanded research in psychology, and led to explorations for pedagogy and curriculum development. At that time, the theory listed seven separate intelligences.

Subsequently, with the publishing of Gardner's (1999) “Intelligence Reframed” two more intelligences were added to the list. The intelligences are Verbal/Linguistic, Logical/Mathematical, Visual/Spatial, Bodily-Kinesthetic, Musical, Interpersonal, Intrapersonal, Naturalistic, and later one named Existential/Spiritual.

Gardner (1983) wrote about the fact that students daily use one, perhaps two, of the nine intelligences as their primary intelligence and to learn and interpret the world best through it. The Theory of Multiple Intelligences has several implications for teachers in terms of classroom instruction. The original theory (Gardner, 1983) states that all intelligences are needed to productively function in society. In traditional education systems Gardner (1983) describes that there is typically a strong emphasis on the development and use of verbal and mathematical intelligences. While some teachers also integrate other material or use other approaches to enrich the education of their students, Gardner (1983) argues that not all of these nine intelligences are used daily in most schools. This author feels there is more teachers could do to incorporate the majority of Gardner’s (1999) nine intelligences and that virtual teachers in particular may find it beneficial to follow his guidelines to recognize and teach to a broader range of talents and skills.

Using this possibility, Gardner’s (1983, 1999) work to structure the presentation of material in a style which engages most or all of the intelligences can encourage the use of technologies commonly available. For example, showing virtual reality or augmented reality information, playing TED talks, using phone apps, using hands-on manipulatives both in the physical realm and in the virtual realm creates and recreates multi-sensory education. To see and touch a concept; to create videos and songs, and to walk in an environment using virtual reality and mixed reality technologies, is to implement taking the technological “deep dive,” so to speak. These kinds of presentations not only excite students about learning, but place the student

into the environment itself. These methods also allow a teacher to reinforce the same material in various multi-sensory ways. This approach activates different parts of the brain, and affirms a wide assortment of intelligences. Teaching to all nine of the intelligences may therefore help many students facilitate a deeper understanding of the subject material.

This author believes it therefore makes sense not to limit presentation of educational material to just the Verbal/Linguistic, Logical/Mathematical, and occasionally to use some of the other intelligences. A solution to re-engaging students in our school may be more fully to integrate all nine intelligences, using the multi-sensory approaches to teach to them, by them and through them. By developing virtual and physical materials that address each of these intelligences, it follows that sensory approaches encompassing all nine might be used to excite the students in their learning. Using a virtual multi-sensory approach might empower a student who has not been engaged in learning before, or re-engage a student who has found learning difficult.

Gardner (1983, 1999) undertook both psychological study and neurological research as a psychologist and educator. For educators, the direction of application of his research may to harness intelligence and inspire the mind, including ways to improve a student's ability in any given classroom, harnessing the senses and the talents of each student. Multi-sensory education is implied by Gardner, because each learner has differences in preferred approaches to learning, and has interests, talents and one or two primary intelligences in addition to the nine elaborated on in “Intelligence Reframed” (Gardner, 1999). See Appendix A for a detailed description of Gardner’s (1999) nine intelligences. The value and application of the multiple intelligences theory is addressed in the next section.

Application of Gardner's Theory in the Classroom

The theory of multiple intelligences has in the past been focused mostly on child development although it applies to human development at all ages. In his initial work, Gardner (1983) presented evidence on the variety of intelligences from many fields of study including biology, anthropology, and the creative arts. Gardner (1993a) also discussed application of the theory to school programs in helping students through the process of learning more quickly and effectively. He proposed using the multiple intelligences approach to more effectively teach the desired curriculum, and to use the students' primary intelligence to do so. One of Gardner's premises is that re-thinking curriculum development can result in lifting up the primary intelligence of each student in the classroom. Curriculum development that allows each student to learn and to show their learning through assessments of various kinds, not just traditional pen and paper, will encourage the student to express himself or herself in different ways. For the teacher, ideas for using each of these intelligences can be integrated into, as well as used to reinforce, the content areas and subject matter by the teacher while doing curriculum planning.

Gardner's background as a psychologist and professor of neuroscience primarily guides the professions in which he works, but spans a number of applications within the field of education. His theory is ". . . an account of human cognition and provides a new definition of human nature, cognitively speaking" (Gardner, 1999, p. 44). Gardner argues that the big challenge facing the best use of our talents in life and learning is ". . . the uniqueness conferred on us as a species exhibiting several intelligences" (p. 45). He ponders whether educational systems might need changing (Gardner, 1993, p. xxiii) to allow the student to reach his or her fullest potential. He notes that

> … constraints that exist in the mind can be mobilized to introduce a particular concept (or whole system of thinking) in a way that children are most likely to learn it and least likely to distort it. Paradoxically, constraints can be suggestive and ultimately freeing. (p. 45)

However, this author believes that although it began there, it should not stop there. Gardner (1983, 1999) has indicated above that each intelligence occupies a different area of the brain's structure and therefore exercises different connections in the brain. The brain should ideally be fully exercised.

As an educator, this author's sense is that if each of these intelligences were a common part of the learning environment, when combined with a particular virtual or physical classroom methodology, it could result in students having an increased self-worth because of the process of building on their strengths. This author's teaching experience also supports that students with a sense of self-worth can be more engaged, can enjoy their environment, may find out more about themselves, and may further enjoy being part of the school system at Engaging Virtual Academy (EVA). EVA is a pseudonym for my school, to protect the confidentiality of my participants.

Incorporating the nine intelligences in my EVA curriculum may also allow my students to share with others how they have expertise in certain areas. Additionally, students may develop strong problem-solving skills when they use virtual technologies such as virtual reality, mixed reality and video modeling to meet real life situations. This now leads the writer to other educators who use experiential methods to help children learn.

John Dewey

John Dewey was a proponent of experiential learning. Dewey reflected on the pedagogy of learning through direct experience, by a process, or cycle, of action and reflection (1938/1997,

pp. 5-7). This type of learning differs from traditional education in that teachers first immerse students in action and then ask them to reflect on the experience. Dewey commented that in traditional classrooms teachers begin by setting knowledge (including analysis and synthesis) before students, and have them learn before doing. Dewey's approach differs, and includes a process of exploration involving experiential learning cycles (ELCs) which intrinsically include the learner's subjective experience as critically important. Dewey elaborates that ELC models are among the most important pieces of theory used in many outdoor education programs. The underlying philosophy of ELC models is to emphasize that the nature of experience is of fundamental importance and concern in education and training as is the end result (1938/1997, pp. 7-9). Dewey believed that human beings learn through a hands-on approach involving experience, reflection, and then planning for new experience. From Dewey's educational point of view, this means that students must interact with their environment in order to adapt and learn.

John Dewey developed and endorsed structured, experience-based training and education programs. In his model of an experiential learning process, students of all abilities begin taking on new active roles. Dewey emphasized that students participate in a real activity with real consequences, and that this causes learning to synthesize (1938/1997, p. 9). Dewey also asserted that in the learning cycle of experiential education, teachers become active learners, too, experimenting together with their students, reflecting upon the learning activities they have designed, and responding to their students' reactions to the activities. In this way, teachers themselves become more active; they come to view themselves as more than just recipients of school district policy and curriculum decisions (1938/1997).

In summary, Dewey's responsive experiential learning cycle (ELC) model involves first that students go forth and have an experience, then return to the classroom or to another setting

to review what happened and what can be learned, and then work collaboratively to plan a way to tackle the next round of experience. The significance of Dewey's work for this project is that the hands-on, multi-sensory development of educational curriculum and process is pivotal to learning as is create an ELC. This author believes that Dewey's methods and models are important for this project because creating an ELC will guide how virtual tools and new technologies are used.

Employing ELC's may lead teachers to create potentially exciting and deeper learning possibilities for use both in the traditional classroom and in the virtual environment. Dewey's work was paralleled by others in different parts of the world, including in Italy. The writer will now explore Maria Montessori's work, which prioritizes another kind of experiential learning.

Maria Montessori

Maria Montessori was born in 1870, the same year that Italy became a unified nation. Her approach to experiential education was unique. She broke traditional roles between male and female, teacher and student at a very young age. She studied anthropology at university, and then became the first physician licensed in Italy.

In the Montessori Method (1912) Dr. Montessori described her greatest interest in the field of medicine: medical care and education for persons with developmental disabilities. In 1897, Dr. Montessori had revealed that she felt mental deficiency presented ". . . chiefly a pedagogical, rather than mainly a medical, problem" (1912, pp. 32, 35). Students who were mentally deficient began to flourish under her model of education, and her published works changed the Italian government's approach to education for these children.

Montessori began to develop the "Children's Houses" (1912, pp. 43-44). Children younger than three and four years old began to read, write, and initiate self-respect. The

unconscious absorbent mind (ages 0-3) and the conscious absorbent mind (ages 3-6) were terms defined by Montessori. Dr. Montessori saw in the children an innate ability to absorb the learning culture, and far more than reading and writing. This was done through interacting with the world around him or her in physical ways. The natural environment, she indicated, was their best teacher. Montessori reflected: ". . . it was their excitement for botany, zoology, mathematics, geography, and all with the same ease, [learned] spontaneously, and without getting tired" that thrilled her (The Absorbent Mind, 1967, pp. 56, 68). Montessori (1967) reflected that the child's mind develops like a sponge, naturally, acquiring skills to move and control his or her body and space, taking in information and knowledge from all around him/her first without thought or choice -- the unconscious stage (pp. 69-72) and later shifts to the social, justice, and moral stage of development, or the conscious stage, through intentional focus on experiences.

Montessori (1912) developed a method that thoroughly immersed children in a multi-sensory system: a broad and tactile system of works by which children could learn hands-on. The first structured multi-sensory pedagogy was born (pp. 41-44), through which the teacher was to allow the child to explore independently, to awaken and to proceed into fuller awareness of their individual capabilities. This was to occur through love, respect, and independent discovery (pp. 37, 43). Montessori (1912) prioritized the question of the education of the senses, noting that it was of important pedagogical interest" (p. 213) and, ". . . education of the senses is most important from both these points of view. The development of the senses indeed precedes that of superior intellectual activity and the child between three and seven years is in the period of formation" (p. 216).

Montessori (1912) realized that the size of the learning environment was also a multi-sensory issue. She initiated child-sized tables and chairs, mats, and other learning spaces made for the students. She is sometimes referred to as the one who discovered and revealed the qualities of children different from, and higher than, those usually attributed to them, both in the ways that they learned with all of their senses, and the encouragement of their spirit (1912, p. 20, pp. 95-100). A fuller description of this approach, both multi-sensory and spiritual, is contained in Appendix B for the reader.

Montessori's belief in children's hands-on and multi-sensory immersion is pivotal in the educational field. A whole section of her 1912 work is devoted to detailed work on the use of the senses in education and the detail of each of the senses within the curriculum (pp. 185-218). That children begin the conscious stage of learning in their preschool years is parallel with what Jean Piaget will call the sensorimotor stage (see below, the next section).

Montessori's work in the field of multi-sensory, hands-on, experiential education is significant to this project regarding the integration of virtual technologies in that it paves the way for multi-sensory approaches to curriculum. When used with many different technologies, the student may synthesize information more effectively. Her methodology extensively pre-figures both medical and educational research on sensory integration, neurodevelopmental theory, child development models, and multi-sensory experiences, as applied to education. These are factors the author believes to be important for multi-sensory pedagogy in virtual education, as well for pedagogy in the traditional classroom. It is the neurodevelopmental and sensorimotor factors in the educational process that this author will explore next.

Sensory Integration and Neurodevelopmental Theory

Sensorimotor development and sensory integration is a major issue in the work here presented. Thompson (2011) notes that Botts, Ayres, Bundy, and Lane, Fischer, and Murray (as cited by Thompson, 2011) pose the following variables as necessary for good multi-sensory experiences. These are:

- plasticity of the brain (the ability of the brain to reorganize neural pathways from previous experiences to new experiences);
- the developmental sequencing of sensory integration that occurs in a child that is a prerequisite for the development of higher cognitive processes;
- overall levels of brain function and intelligence (which may be interpreted as the developmental age of the child, whether it be different than the chronological age or concurrent);
- adaptive possibilities in the child, which are critical to sensory integration; and
- the proximal development, or inner drive, present in each person which aims to develop sensory integration through participation in sensorimotor activities.

Botts (2006) indicates that sensory integration theory is presented by examining three steps:

- that it is a fact that the learning of material is pivotal upon the ability of the student to receive sensory information, process that information, and integrate that information into a plan;
- to ascertain whether there is a deficit in processing and integrating sensory input, which might lead to a disability in planning; and

- an approach to improve sensory integration via material that develops, through sensory experiences, an increase in the ability of the central nervous system to process and integrate sensory information (Botts, 2006).

Neurodevelopmental theorists such as Thompson, Botts, and Ayres, among others, are significant to this project in that they ask questions about the human mind and its processing of sensory experience. As the developer of this project's curriculum it is important that this author consider these questions important to both the medical and the educational worlds, regarding children's development and learning. It is a premise of this author that when all the senses are used, and sensory input is processed well, children have the potential to learn better. Researchers continue to study neurodevelopmental processes both in the medical and educational fields. Historically, Jean Piaget is an early theorist, whose psychological and neurodevelopmental connections to education and development were clearly expressed, and he is the author we now approach.

Jean Piaget

Piaget asserted that his theory was a "genetic epistemology" (as cited by Kitchener, 1986) because he was primarily interested in how knowledge developed in human organisms. Piaget's training in Biology and Philosophy and concepts from both these disciplines influences his theories and research of child development, thus this may be termed a neurodevelopmental approach or theory. In fact, Piaget states that one must first analyze the biological origins of development, and then analyze the epistemological consequences with which it ends (Inhelder and Piaget, 1976). He shares three groundings for this genetic epistemology (pp. 11-23):

1. The adaptation of an organism to its environment during its growth, together with the interactions and autoregulation which characterizes the development of the "epigenetic

system." (Epigenesis in its embryologic sense is always determined both internally and externally.)

2. The adaptation of intelligence in the course of the construction of its own structures, which depends as much on progressive internal coordination as on information acquired through experience.

3. The establishment of cognitive or, more generally, epistemological relations, which consist neither of a simple copy of external objects nor of a mere unfolding of structures pre-formed inside the subject, but rather involve a set of structures progressively constructed by continuous interaction between the subject and the external world.

Over a period of six decades, Piaget conducted a program of naturalistic research that has profoundly affected our understanding of child development. The concept of cognitive structure is central to his neurodevelopmental theory. Piaget laid out a system of cognitive structures or patterns of physical or mental action that underlie specific acts of intelligence, and correspond to stages of child development (pp. 45-62). In fact, he starts his theory regarding biology and cognition by stating

> . . . that the former are an extension and utilization of organic autoregulations, of which they are a form of end product. To demonstrate this, one can begin by noting the close parallels between the major problems faced by biologists and those faced by theoreticians of the intelligence or of cognition. (p. 45)

The reader can perceive how closely linked Piaget proposes biological and cognitive processes to be. This bio-cognitive theory of knowledge shares Piaget's beliefs about the process of how knowledge develops, unfolding developmental stages for children that is based on the innate

ability of a child to develop, and that in part is determined by their cognitive ability, which Piaget believes is genetically based (thus, genetic epistemology).

There are four primary cognitive structures (i.e., development stages), according to Piaget: sensorimotor, pre-operations, concrete operations, and formal operations (Ginsburg & Opper, 1988). In Piaget's theory of development, learners think in distinctly different ways at different stages of cognitive development. He declared that as learners grow, they mature in their thinking (Osoje, 2008). Osoje shares that the importance of this process of learning in the educational environment is that educators can understand learners better and create their lessons [in mathematics, in his case] with understanding of where children are in their thinking processes to ensure mastery of educational goals (p. 26). Piaget had classified learners at various stages not based on what or how much they know, but rather on the basis of how they think. He asserted that this classification is part of how all people develop when they develop at a certain age in typical ways; one might think of these cognitive developmental stages as benchmarks, so to speak. A detailed description of these stages is contained in Appendix C.

There is bias in this approach apparent to this researcher. Piaget had research published in journals about genetic psychology, child care, urban education, awareness or consciousness, recollection, reconstitution, and conceptualization of ideas in youth and adolescents. He had explored science education, cultural variables, and the needs of the classroom teacher. For example, with children in the sensorimotor stage, Piaget believed teachers should try to provide a rich and stimulating environment with ample objects to play with. On the other hand, with children in the concrete operational stage, Piaget believed that learning activities should involve problems of classification, ordering, location, conservation using concrete objects. This author

asserts that Piaget’s theory goes right along with a multi-sensory approach, though it appears that less of a sensory approach is used by Piaget as the child gets older.

Conversely, however, this author asserts that Piaget's theory results in specific recommendations for a given stage of cognitive development. This does not work for many children, given that their cognitive development may vary, and appears to be a mix of stages and ages for each topic studied. The greatest problem this author has in critique of Piaget’s approach is that it seems to apply mainly to typically developing students. Although the process may be similar, many students, including special education students, cannot be classified properly (according to age and skills) in the same way that typical children can. Children with conditions, such as autism in particular, may be very advanced in one area, typical in another, and delayed in yet another. Additionally, cognitive structures change through the processes of adaptation: assimilation and accommodation, and are not only genetically determined. Assimilation involves the interpretation of events in terms of existing cognitive structure whereas accommodation refers to changing the cognitive structure to make sense of the environment.

Montessori (1912) would differ with Piaget had she had the opportunity to discourse with him, as she would have had argued that the nervous system and the senses work together to receive information, and that this experience of any child changes the mind as it grows, producing tangible results in the motor pathways as well as the senses (p. 223). She would conclude that we are changed by our experiences, not merely by our genetic makeup, thus a genetic epistemology cannot be the whole; and, she lauds the senses as primary educators, not just the genetic potential for the same. She indicates the senses lead us to learn and then to change how we learn, however developed students would be at any stage of life [a lifelong task]:

> . . . with the peripheral sensory system, gathers various stimuli from his environment. He puts himself thus in direct communication with his surroundings. The psychic life develops, therefore, in relation to the system of nerve centres; and human activity which is eminently social activity, manifests itself through acts of the individual—manual work, writing, spoken language, etc.—by means of the psychomotor organs. (pp. 223-224)

Montessori's conclusion is that both nature and nurture go together:

> Education should guide and perfect the development of the three periods, the two peripheral and the central; or, better still, since the process fundamentally reduces itself to the nerve centres, education should give to psycho-sensory exercises the same importance which it gives to psychomotor exercises. (p. 224)

Additionally, no child is a blank slate: well-trained educators know that. Each child's early experiences are different, and are culturally as well as family-based.

As we approach the application of these theorists' perspectives on multi-sensory education, we must now turn to the virtual educational environment and the ways in which such multi-sensory methods may be applied to the virtual educational classroom. In the next section, we will explore the ever-developing virtual educational pedagogy, research, and discoveries that may be of help in the implementation of pedagogy and best practices.

Virtual Education

In this last section, this author will strive to integrate the use of virtual technology to the above three sections. How will multi-sensory learning, multiple intelligences knowledge, experiential education, and neurodevelopmental theory work together to provide great strategies for students learning science in a virtual education setting? How will application of these facets work and what are the strengths and weaknesses of such a form of education? What tools can be

used – electronically and virtually – to link a student to realistic and exciting inquiry in science? The school I work for, EVA (a pseudonym for my school to maintain the privacy of its participants), uses nationally based materials sent to students for both hands-on and virtual learning. In this environment virtual learning strategies, learning management systems, wikis, jings, interactive applications, and Google applications are used.

Virtual reality. There is much more to learn from recent technology that could enhance multi-sensory learning in the virtual environment. As far back as 1993, Dr. V. Pantelidis wrote about the use of virtual reality (VR) in medicine, entertainment and design. Pantelidis (2010) is among the best of those researchers working with VR technology in education. She stated that there are many benefits to using VR stating,

At every level of education, virtual reality has the potential to make a difference, to lead learners to new discoveries, to motivate and encourage and excite. The learner can participate in the learning environment with a sense of presence, of being part of the environment. (p. 61)

Pantelidis (2010) shares the following reasons to use virtual reality in education:

- VR provides new approaches to visualization, drawing on the strengths of visual and interactive materials.
- VR provides an alternate method for presentation of material. In some instances, VR can more accurately illustrate some features, processes, and procedures than by other means. This is because it can zoom out or zoom in, rotate or immerse the student in the item being examined. The types of close-up examination of an object, or the manner of observation from a great distance, or the alternatives for observation and examination of areas and events in the content areas are unavailable by other means.

- VR motivates students. It requires interaction and encourages active participation. Some types of virtual reality require student or groups of students to work in collaboration by entering into the VR together, and interacting with something in that virtual reality; it provides both an educational and a social atmosphere.
- VR allows the learner to proceed through an experience during a broad time period, over class periods and as extension of class periods, not limited by a regular or fixed class schedule, and at their own pace.
- VR allows those who are differently abled or differently talented to participate in an experiment or learning environment, perhaps in ways they cannot do so otherwise.
- VR may transcend a number of language barriers, when with chosen language-friendly text access. This possibility can provide global access and equal opportunity for communication with students in other countries or cultures, including allowing the student to take on the role of a person in a different country or culture.

Pantelidis (2010) quotes Winn (1993), indicating reasons to use virtual reality in education and training relate particularly to its capabilities. Winn (1993), in *A conceptual basis for educational applications of virtual reality*, states that:

- Immersive VR furnishes first-person non-symbolic experiences that are specifically designed to help students learn material.
- These experiences cannot be obtained in any other way in formal education.
- This kind of experience makes up the bulk of our daily interaction with the world, though schools tend to promote third-person symbolic experiences.
- Constructivism provides the best theory on which to develop educational applications of VR.

- The convergence of theories of knowledge construction with VR technology permits learning to be boosted by the manipulation of the relative size of objects in virtual worlds, by the transduction of otherwise imperceptible sources of information, and by the reification of abstract ideas that have so far defied representation. (pp. 61-62)

Winn (1999) concluded that VR helps students to succeed. He notes that many students fail in school due to not being able to master abstract symbols nor hands-on practices of the disciplines they study, although they are perfectly capable of learning the facts, or concepts. He notes that ". . . VR provides a route to success for children who might otherwise fail in our education system as it is currently construed" (Quoted by Pantelidis, p. 62). This is because it is multi-sensory in nature, and one can participate and interact with the material more intensively. However, VR is constructed information and does not include real recorded pr real-time information; it is simulated reality, not true reality itself.

Augmented reality. Augmented reality is another newer term used in virtual education. The term Augmented Reality (AR) is synonymous with mixed reality in the world of technology, and is a combination of reality and VR technology; the term immersive media is also used, and refers to both AR and another technology combined - an even richer possibility. Both AR and immersive media integrate digital information with the real surrounding physical environment, and can be used live and in real time.

In AR, a real-world environment whose elements are augmented by any number of reality-based informational factors are presented as primarily visual experiences, displayed either on a computer screen, or through special stereoscopic displays. Many newer simulations include the additional sensory information, such as sound through speakers or headphones including touch, smell, and taste and are often panoramic - that is, one can turn all the way around inside

the display to see the content at all angles. Some advanced haptic systems now include tactile information, generally known as force feedback, to simulate true motion and feeling, both in medical and gaming applications. With AR, users can interact with a virtual environment by using standard input devices such as a keyboard and mouse, on a smartphone or tablet, or through multimodal devices. Some such multimodal devices are a wired glove, a boom arm, or an omnidirectional treadmill.

AR immerses one in an environment, but it is not to be confused with VR technology. Because it uses added multi-sensory factors that include real sounds, real sights, real motion or somatic feedback, and even real smells, Augmented Reality (AR) alters one's current perception of a real world environment, whereas Virtual Reality (VR) replaces the real world environment with a simulated one. In both VR and AR, haptics are advanced considerably for motion and somatic feedback in education and physical training (pp. 152-165).

AR is able to combine real life with a superimposed image or animation, using the camera on a mobile device, or a special headgear. While the special headgear can be expensive, the potential to use a mobile device's camera holds potential for more universal access to the technology. Everything except the olfactory mode would be able to be provided by the camera and its mobile device and its applications, or the special headgear; added smell would have to have an additional dimension of equipment involved in more complex and likely more expensive immersive media.

AR and VR technologies are constructive in nature. As the student becomes engaged and immerses himself or herself in the material, various pathways may be taken and it becomes ever more exciting and challenging to learn. By immersion into an environment in three dimensions, by entering and interacting with an environment, and by doing so in three dimensions (3D)

Pantelidis (2010) notes that the student becomes part of the concept being studied (pp. 62-64). Because VR and AR technology may allow a more accurate illustration of a concept or process in a content area, it creates enhancement of existing pathways and forges new learning pathways, as it allows both an overview and a close-up examination of an object or concept.

Integration of Multiple Intelligences and VR/AR

Reflecting on Gardner's multiple intelligences (1999), it is apparent that VR and AR may help students with visual or auditory, tactile or kinesthetic intelligences to flourish in their learning. For those with interpersonal or intrapersonal intelligences there are three ways that the use of VR and AR might be of use. First, for individuals with these two intelligences it becomes more possible to develop insights based on new perspectives from others, through interacting with systems and people also simultaneously using the VR technology. Secondly, it can allow people with interpersonal and intrapersonal intelligences to interact in real-time that may help them to synthesize their own learning. Thirdly, it promotes analysis after taking in the new information both from the interactions with others or from their own insights.

As VR allows objects to zoom around or to be rotated, a student's visual or spatial intelligences may be enhanced. For example, a student can view a model of an object from the inside or the outside, from the top or bottom; this creates perspectives and models that engage. For example, in science an atom, a molecule, or a cell may be modeled in VR so that students can zoom in, can study it in detail, even minute detail; learners may go inside it and literally walk around within it, view and become familiar with its parts. As VR also allows one to zoom out, to view and interact with an object from a distance, see it in its context, showing the system, and the whole rather than just the part. For example, in a sociological context a VR model of a city or a social system may give a student a different perspective on intersectionality. In psychology or

human science, the understanding of human beings interacting with one another, with their buildings, streets, and with open areas may make social systems and their concepts come alive.

Pantelidis (2010) posits that results are only obtained with the material when students continue interacting, and the feedback is more immediate that way, exploring from multiple facets the real world, and models and possibilities created from it, thus allowing new creativity and producing fresh insights (pp. 63-64). VR and AR allow students with multiple intelligences, those with talent or ability differences -- including those with handicapping conditions -- to participate in an experiment or move through a learning environment even when they cannot physically or mentally do so otherwise. Not only learning by doing in ways that they may never have the potential to do otherwise, VR and AR also allow a learner to proceed through an experience at his or her own pace. The learner actively decides the next pathway may return to the material at another point and explore an alternate pathway at another time (p. 64).

For both teacher and student, with VR and AR, time frames may be modified, thus allowing repeated access to material, overviews and details, or deeper interactions over time, both inside and outside of the classroom. A constructivist approach assists the learner to learn by doing, then to reflect on his or her experiences, also promoting the construction of a Dewey-like experiential learning cycle (ELC) through the action-reflection-planning models. It permits a student to move through an experience during a broad time period not fixed by a regular class schedule. VR provides experience with new technologies through actual use via simulations of environments for vocational learners; AR and immersive media promote understanding using real video and interactive materials and environments.

Programs and Applications Using VR and AR

The following programs are currently available for Google Cardboard in AR and VR.

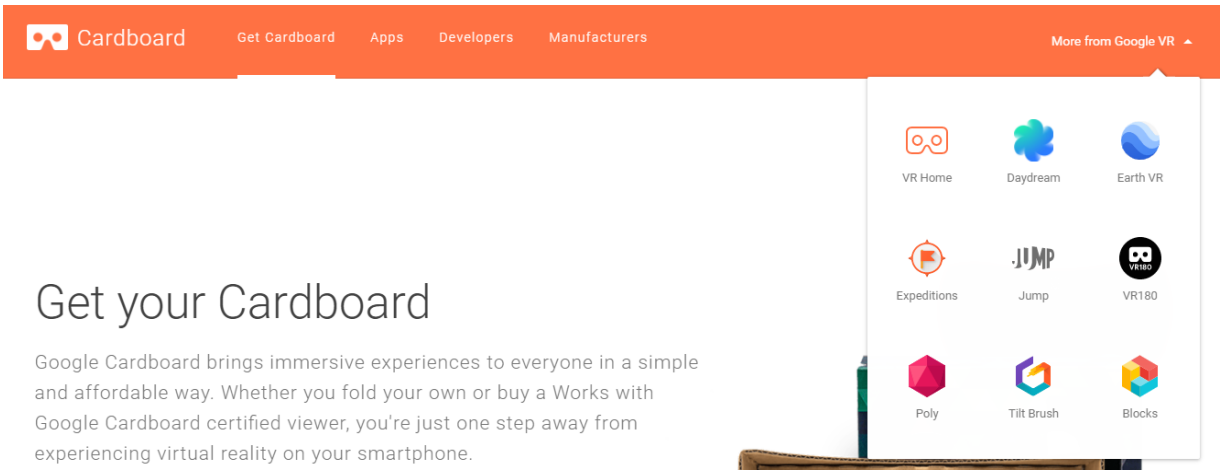

Figure 1. Google Cardboard Applications Spring 2018

Some VR and AR programs that allow students to learn technology, mathematics, engineering or science are:

Construct3D - a system that allows 3-D printing and the development of printing and technical software.

Elements 4D - a Chemistry application available from the Apple iTunes store.

SkyView - An astronomy application available on the Google PlayStore and from the Apple iTunes store.

SketchAr - an application on Google PlayStore or Apple iTunes store that helps people learn to draw anything they need to, to record the world around them.

AR Circuits - an application on Google PlayStore or Apple iTunes store that helps students study circuits and electricity.

Anatomy 4D - an application that is free and interactive that teaches anatomy with real medical images.

Science AR - an application for schools that makes science come alive.

Zoo AR - an application with a variety of vertebrate and invertebrate animals that shares viewing them in three dimensions.

Elements 4D - A game and story application that helps students use AR to learn chemistry and its applications.

There are systems for teachers to use to teach using VR and AR technologies; four of these are:

Zaption - an application that allows access to make videos interactive for students and gives analytics back from the students for teachers to inform instruction. It was

Engage Platform - http://immersivevreducation.com/engage-education-platform/ and associated store http://store.steampowered.com/earlyaccessfaq/ containing myriads of developed and developing games for all users, including education, science and technology, some of using keyboard/mouse, special tracked motion controllers, or gamepad controllers (allowing flexibility and budgetary control). Some are free, some have a cost associated with purchase. The possibilities for multi-sensory education involve a full range of visual, auditory, haptic, tactile and interactive choices.

RedboxVR (R) - http://redboxvr.co.uk/ is a whole system for teachers that sells classroom VR kits, and contains lesson plans for teachers. The benefit of the system is that it is associated with Google Expeditions, free on Apple iTunes or Google Playstore. The RedboxVR kits help provide total multi-sensory experiences for students.

Google Expeditions - All that is needed is a smartphone, and a simple cardboard, or more complex, phone-insertable viewer (one can also just turn their smartphone sideways). One can take tours of various topics, become involved with others in a planned expedition, or create and lead their own expeditions. It can be integrated with Google Classroom and Google Slides, as well as Google Sites.

At Hamline University, the Google Site https://sites.google.com/a/hamline.edu/ldong03-research-group/ is "The Hamline University Renewable Energy and Environmental Research Laboratory." It utilizes chemistry, physics, and materials science in the pursuit of creating novel materials and devices. Projects are mainly focused on synthesis and characterization of nanoscale structures and seeking ways to apply them towards nanoscale devices for use in many fields, including electronics, energy conversion, energy storage, and water purification. This laboratory is at the university level, but could be scaled for any course at the level desired, through a Google account/system in an educational organization. The project or site that a teacher could create around a particular content area could have endless possibilities when used with the multi-sensory Google Expeditions and Google Classroom dimensions.

Limitations and Dangers of VR and AR in Education

Pantelidis (2010) reflects that VR and AR technology is likely to be expensive and to take training to understand. Teachers may need to teach the technology first, depending on the level and experience of the students. The logistics of using the technology may outweigh the problems with travel to a particular location, such as a field trip, or the technology may actually be preferred because the VR dimensions are better or allow deeper interaction with material. Prejudice may exist against the technology itself, though this may be less of a problem for those already educating with technology (p. 65).

There may be physical side effects to using VR and AR. Lamott (2017) of CNN reported in a December 13, 2017 article and newscast that trips, falls, and injuries have been reported by VR and AR users. She states that close supervision of students is therefore mandatory. In homes, other people, pets, ceiling fans, and furniture have become involved in accidental contact while using VR and AR equipment, especially those that can be worn (p. 2). Eye problems, dizziness,

headaches, even motion sickness symptoms including nausea have been reported. Lamott reported that application developers have discovered this is a result of our eyes and brain and how they normally produce sensory information. The brain also perceives that something is farther away, when it is really inches from the eye, thus producing sensory conflict with the surrounding environment (p. 3).

In addition, persons with pre-existing conditions may experience side effects that are more dangerous. People with conditions such as vision abnormalities, hearing abnormalities, heart conditions, psychiatric disorders, or epilepsy and other seizure disorders may be affected by VR and AR use. It would be a safety concern that those who are pregnant or elderly be advised not to use VR or AR devices because of fall risks (p. 4).

Stanford University's director of the Virtual Human Interactions Lab, Jeremy Bailenson (2018), who uses VR himself and on subjects in his lab daily, advises children should use VR and AR for only short periods of time and infrequently. For true VR and AR headsets, Bailenson notes that most major manufacturers have set a cutoff age: no use of the device for children under the age of 13 (p. 427). Bailenson notes,

> There are dangers and many unknowns in using VR, but it also can help us hone our performance, recover from trauma, improve our learning and communication abilities, and enhance our empathic and imaginative capacities. Like any new technology, its most incredible uses might be waiting just around the corner. (p. vii)

A solution to these problems has arisen. Google has developed the Cardboard viewer, which is not a wearable device, but is hand-held, with a smartphone placed securely inside it. There are a number of inexpensive viewers much like it, which put the average smartphone to work as a VR or AR device, cutting down on the cost, eliminating the "wearing" of these

devices, and therefore minimizing potential side effects that come from the intensive use of, or the length of use of, the more complex and wearable devices.

The Benefits of VR in Education

According to presenters using the latest in VR tools, students can become immersed in the lesson, discover multi-sensory modes of experience while being immersed, and may be able to use most of their senses while learning. Providing students access to VR and AR tools might provide them control over which pathways they choose, or according to Gardner's (1999) multiple intelligences which modes of learning might work best for them, or how their many senses and the interaction with the content in VR and AR form; this might better be used to enhance the multi-sensory nature of their understanding. Students might therefore be able to choose which kind of learning and feedback they would best be able to use, to magnify their learning, work according to their understanding, enhance their best learning modes or intelligences, and enrich their interest.

The United States Department of Education (2010) has explored the use of interactive technology in learning with the use of the application Zaption, a teaching tool that was funded by the U.S. Department of Education. Zaption involves an interactive video platform, with teacher-developed images, text, drawings, and questions embedded within the process of video education. Zaption was developed so that interactive strategies would reinforce material using tactile, auditory, verbal, and visual methods and feedback, as the students watched the video. In addition to Zaption 3D systems are also being developed for use in STEM education.

At the International Conference on Virtual, Augmented and Mixed Reality (VAMR) 2014, a paper was presented outlining 3D systems for STEM education. Researchers Ma, Xiao, Wee, Han, and Zhou (2014), from the Department of Electrical Engineering and Computing

Systems of the University of Cincinnati, presented a paper on the role of new “mixed reality” hands-on technology. The authors described how an AR technology employs an advanced hand gesture interface. With this, interface, a student wearing the device might be able to flex and manipulate objects in a virtual learning process with one or both hand. According to Ma et al. (2014) new AR hands-on technology allows students to use their muscles, vision, hearing, and sense of touch, and feel as if they are experiencing the real thing.

Placing these new VR and AR reality technologies using inexpensive Google Cardboard (or equivalent viewers) into the hands of our EVA students might allow them to become more immersed in their lessons using all of their senses for short periods of time. Alternately, deploying VR and AR-like technology to students using existing non-wearable technology options, via computer, mouse and keyboard, game controller, smartphone or tablet technologies, integrating any of the 3D systems in VR and AR or mixed reality technologies, would likely produce fewer side effects and be amazing opportunities to enhance the virtual students’ learning experiences.

Conclusion

The thoughtful reader will most likely be excited to connect the multi-sensory approaches aforementioned, with the experience-based and sensory-based, educational and neurodevelopmental information provided by such educators as Dewey, Montessori, and Piaget. The reader may also now connect the multiple intelligences theories of Gardner and the experiential cycles spoken of by Dewey to the opportunities provided by the VR and AR / mixed reality technologies available to both scientists and educators. It is with this thrilling vein of a possible integrated approach that this writer proceeds to share with the reader the projects and methods for a unit of science curriculum set in the virtual school environment (at EVA, the

writer's virtual school). In Chapter Three this author will now unfold the pedagogy and methodology for developing this unit of curriculum, using the student-based constructivist classroom approach.

CHAPTER THREE

PROJECTS AND METHODS

Overview of Chapter

The study was prepared by the author to empower students in a multi-sensory approach, to learn in the virtual environment using virtual reality, augmented reality, and virtual technology that supplement current traditional classroom techniques and that enhance education. “What are virtual tools and multi-sensory strategies that can be integrated into curriculum development to support the engagement of learners in science in grades 3-5 in virtual learning environments?” ultimately leads to the discoveries needed to make it happen. Using technologies that enhanced the multi-sensory possibilities for education, these tools expanded a curriculum in programs for science in the elementary grades.

By integrating the use of these technological tools, which are currently lacking in traditional classroom or virtual education, this research provided avenues for enlivening curriculum using virtual technology tools currently available but largely unused at present. The intent was to provide enriching curriculum harnessing multi-sensory experience, experiential learning cycles, and differentiation using these technologies in multiple dimensions for virtual classrooms. Development of a curriculum unit was undertaken with the intent to expand and enliven a multi-sensory system for virtual education, with the use of the Understanding by Design (UbD) (Wiggins & McTighe, 2011) methodology, framed into a constructivist and virtual approach. This seemed the most apt model for the curriculum project.

Readers may find deep ties both to Gardner’s Multiple Intelligences theory (1983, 1999) and methods, and Montessori’s methods (1912, 1956), as well as Deweyan philosophy

(1938/1997) that were used to develop the curriculum. The ease of using UbD (Wiggins & McTighe, 2011) within the assessment and planning phases, after the goals for the unit were outlined, were methods that had an intrinsically multi-sensory nature. Appendix E shares the template for UbD lesson planning.

The author developed a two-week (ten day) unit of curriculum with a follow-up Estuary Fair held a week or two after the unit, to be eventually applied to a constructivist-based virtual classroom. This unit was changed from a classroom-based unit to a virtual unit by re-writing by reconfiguring face-to-face lessons, and re-fitting the technological possibilities into a virtually-based environment. Using the UbD (Wiggins & McTighe, 2011) curriculum design method, the unit shared a multi-sensory and multi-dimensional approach to learning.

Organizational Structure

The author chose to use the template from Wiggins and McTighe (1998) and the Association for Supervision and Curriculum development for this unit. It is found in Appendix E, copied from resource lists in their 1998 book *Understanding by Design,* a book first written and later updated to offer lesson, unit, and course design and content processes. According to the updated Wiggins and McTighe (2011), UbD is called "Backward Design." The authors described how backward design was different from the approach taken by many instructors who design curriculum from the start to the finish, in a "forward design" manner. In a forward design process, teachers considered learning activities and content, then they developed assessments around their learning activities, then attempted to draw connections to the learning goals of the course. UbD, on the other hand, considered the desired end result first.

In the Wiggins and McTighe (1998) approach to curriculum design the first step for this unit was to determine the learning goals. These goals took the objectives to the very end: what

the teachers wanted their students to have learned when they have finished the material. The goals were established, and the second stage involved the consideration of assessment. The choices of assessment type and mode then drove how the lessons were to be developed. This was a very intentional process, and different than other models of curriculum development.

Identifying the Curriculum Development and the Rationale for Selection

Using Understanding by Design (UbD), this author took into consideration the process of learning and the goals of learning first. Using the UbD model and methodology, this author developed a grade 3-5 Ocean Science curriculum unit, discussing estuaries, bays and near-shore biomes, and used multi-sensory educational strategies designed for the virtual environment and employing the tools and strategies proposed by Gardner (1999) and others, discussed in Chapter Two. This approach guided individual students to learn according to their best capabilities, to use their primary intelligences, translated and applied to the virtual educational environment.

In using the UbD approach to create a unit the teacher intended for students to develop open hearts, minds, and experiential learning regarding the care and preservation of estuaries, bays, and nearshore biomes, while also sparking inquiry and passion for the ocean through the projects and the concluding fair. The process developed as the goals and methodology were considered, and the lessons developed from the methodology.

Setting

The setting was a virtual science classroom at Engaged Virtual Academy (EVA), a pseudonym for the school at which the author works, to protect the privacy of the student participants. This was proposed as a future lesson for future presentation to 30-60 students per virtual session, twice weekly in the Blackboard Collaborate classroom. The potential EVA participants were in grades 3, 4, and 5 and ranged from typical students, to gifted students, to

students with learning limitations. The curriculum created for this capstone project had potential to be differentiated for various learning levels (from typical, to gifted, to limited learning levels). In this curriculum, the author used various multi-sensory strategies and virtual technologies, as well as a multitude of resources to differentiate the curriculum for typical students, gifted students, and for those students with modified or adaptive needs due to an individual educational plan (IEP) or 504.

Through examining the multi-sensory approaches and developing the lessons using UbD, a discovery emerged that the student-centered processes for learning, found in the constructivist classroom, and by which the teacher asks open-ended questions to spark the student's curiosity and let the students find discoveries, was primary. Constructivism also connected this author back to the Montessori Method (1912) and its respect for the child and his/her learning process.

Curriculum Development Process

The process of developing curriculum for any UbD unit (Wiggins & McTighe, 1998) involved the use of a template to think about and plan the designed curriculum. The steps using the Wiggins & McTighe UbD template followed. The process began with the goals, proceeding with the assessment process, and then concluded with the development of lessons. UbD itself helped to design this curricular units and the lessons by focusing on the result or outcome desired from the learning process, then working backward to find the best processes, objectives and standards to accomplish that result. Please find the *Understanding by Design Curriculum Development Template* (Wiggins and McTighe, 2008, 2011) in Appendix E.

Constructivism Unfolded

Brooks and Brooks (1999) unfold for readers that in constructivist classrooms, ". . . student-to-student interaction is encouraged, cooperation is valued, assignments and

materials are interdisciplinary, and students' freedom to chase their own ideas is abundant. . . ." (p. 10). According to these authors becoming a constructivist teacher is not simple. It requires ongoing analysis of one's teaching, planning, and practical instruction and methodology in the preparation to teach and in the teaching [which is always and ever a learning process] and ". . . reflective practices for which most teachers have not been prepared" (p. 13). Additionally, constructivist teaching helps learners to transform and construct new meanings and to reach deep understanding (pp. 15-16).

Brooks and Brooks (1999) emphasized that choosing the constructivist paradigm for learning and teaching work toward the human impulse to construct new understandings. When this impulse is allowed to persist, unlimited possibilities are created for students by freeing students from fact-driven curriculums. The Brooks and Brooks (1999) approach can enable a Deweyan approach result: experiences come first, then reflection. Reflection helps to create larger ideas. By working with larger ideas in a process, Brooks and Brooks (1999) believe that placing the power in students' hands to create their pathway helped them to follow interests and to learn transformatively. They introduced to the reader that the world's complexity includes many perspectives on every topic and area of learning. This includes decentration: acknowledging that learning involves others, includes other perspectives, and is not a straight-line, manageable thing; it can be elusive, messy, and exciting (pp. 21-22).

Some students need more structure than others. In the process of the development of the lesson, the challenge was to differentiate the instruction for three levels. Ideas for the unit's extension and adaptations were offered in the curriculum plan to augment the typical lesson process, found at the conclusion of the unit plan.

As a teacher, the methodology of students working in groups, cooperating, and chasing their own ideas as well as collaborating with the small group represented an exciting way to teach. In this author's mind, it requires preparation, flexibility, and trust. For this curriculum, specific challenges will be:

- preparation
- trust-building to create relationship with EVA students and their learning coaches - not being able to meet face-to-face with students and families due to the distance learning
- flexibility - to engage with a new way of learning
- new student roles - encouraging students to explore freely could be challenging because this may not be something they had done in the past

To apply this method requires frequent observations of students at work, which is very possible when applied in the virtual classroom live sessions, and requires student exhibitions and portfolios as they share their knowledge.

According to Brooks and Brooks (1999), the intentionality of constructive classrooms helped to produce supportive feedback, avoided judgmental responses, enhanced motivation to learn, and is an interpersonal approach used by the authors. Brooks and Brooks (1999) then indicate multi-sensory approaches of helping students learn and create may provide useful retention for the future, as opposed to teaching, testing, and moving to the next topic in a disjointed manner. This returns us to the UbD model - the backward chaining approach to creation of curriculum.

Applying this process of constructivism in the classroom, especially the math and science classroom, became of intense interest to the author at this point. Constructivism stresses a student-centered and multi-sensory approach, as well as the usefulness of hands-on

objects to illustrate a point (Brooks & Brooks, 1999, pp. 10-15, 21-22). The authors suggest that hands-on, tactile use of various manipulatives and story-telling provide an experiential framework that may assist learners in engaging material while learning virtually. This encourages, according to the constructive approach, meta-learning: using each's primary mode (of multiple intelligences) of learning, and produces sensory-friendly methods allow learning to be more experiential. This appears to be is a launching pad for meta-learning: to learn, and then to learn how to learn.

Constructive teaching and learning is one answer to the study question, "What are virtual tools and multi-sensory strategies that can integrated into curriculum development to support the engagement of learners in science in grades 3-5 in virtual learning environments?" along with the application of Gardner's theory. When all stakeholders in the educational system engage in relationship, enter into discussion, and open pathways to classroom research while they learn the multiple intelligence, holistic approach to learning, the pedagogy or constructivism can come to life. Igniting the construction of knowledge in the classroom and advance research requires collaboration, the formation of a sense of greater community, and tenacity; researchers and teachers, along with parents and friends can work together to eliminate myths about learning and empower the students and their families (Worden, Hinton & Fischer, 2011, p. 12).

Some characteristics of constructivist classrooms that are most interesting include:

- Encouraging and supporting student initiative, curiosity and independence.
- Letting students' responses guide the way to further study, instruction and content
- Encouraging students to discuss lessons with one another and the teacher
- Using exploratory vocabulary.
- Using assessments that encourage the use of media and multi-sensory response.

- Asking for elaboration in multi-sensory ways
- Giving students experiences that explore or bring up contradictions to their original set of thinking
- Utilizing wait time as part of the process
- Creating relationships and metaphors
- Encouraging natural curiosity
- Using raw data, primary sources, interactive and physical materials that can be sensed and used for learning.

It occurs to this author that the virtual classroom is combined with multi-sensory tools, and technology such as Virtual Reality (VR), then the constructivist classroom becomes an experiential laboratory in which all stakeholders are part of the larger experiment. Teaching using a variety of avenues may also lead to a student-centered response to share learning, in which the students themselves then create materials to demonstrate their understanding of the subject matter in response to an activity developed during a lesson.

Assessment processes designed with UbD, according to Bowen (2017), can be applied and allow the student to choose the type of response for assessment that best fits him or her. For example, a student's project could take the form of a paper, a video, an art project, and expressive or dramatic presentation; it could take the form of a "spoken word" poetic or prosaic form, or a musical form. Allowing a project to take any of these forms, as chosen by the student, encourages each student to use their primary forms of intelligence and to engage actively in response to what has been taught. And, according to Gardner (1999) the concurrent and/or integrated use of a number of these intelligences would

enhance learning; they would be important in triggering various areas of the brain to respond and integrate with regard to learning, and ever so much more interesting an approach to teaching, learning and living than just using one teaching or learning method.

Constructivist teaching helps learners to transform and construct new meanings and to reach deep understanding (Brooks & Brooks, pp. 15, 16). Choosing the constructivist paradigm for learning and teaching work toward the human impulse to construct new understandings, unlimited possibilities are created for students by:

- Freeing students from fact-driven curriculums by working with larger ideas,
- Placing the power in students' hands to follow interests and learn transformatively,
- Sharing that the world's complexity includes many perspectives on every topic and area of learning,
- Acknowledging that learning is not a straight-line, manageable thing but can be elusive, messy, exciting (pp. 21-22).

This author believes that the ability to reflect as a teacher, as a student, and with the group of students and teachers working together, creates a collaborative, engaged community of learners. Then, the possibility for constructivist educational pedagogy opens a doorway.

Using UbD to design curriculum and integration of the virtual tools, including newer uses of VR technology may provide a new way of teaching and learning for everyone. By helping the students use their primary forms of intelligence, interest and involvement increase, and engagement may also increase. The student involved in the virtual classroom and using multi-sensory approaches may find thought, feeling and action come together.

When the student can feel and sense the lesson, while the student is feeling and sensing a paradigm shift may emerge and decentration may occur. A multi-sensory approach and an

experiential approach may operate together with UbD design (Wiggins & McTighe, 2011) quite well and may encourage decentration, the act of getting out of one's own perspective and stepping into another person's perspective to see things from a different angle (Brooks & Brooks, 1999, p. 58). In interactions and relationships and in dealing with other people, problem-solving as a group, collaboration, and creativity are aspects of decentration and of creating new pathways in the world. Decentration additionally requires the conscious acknowledgement that one's own view is one view among many and that there are many other perspectives that may agree or disagree with one's own view and engagement with material in a variety of ways (p. 58).

The curriculum was developed using UbD and in keeping with the constructivist approach. The process of undertaking this curriculum project was reviewed below.

Human Subjects Approval

Presents elements of human subject review as appropriate for the study. The projects used no live human subjects; the author developed a curriculum to be used with human subjects in a virtual educational environment in the future. The IRB application was submitted in March 2018. No data from human subjects was used or developed in the projects, thus it was deemed unnecessary to submit the IRB application; it was exempted from the IRB approval processes.

Limitations

The limitations of this project were that the curriculum was not tested in the virtual classroom "live" with students, it was a curriculum development project only. The author did not consult any colleagues teaching in the virtual environment, although one of the team members for my thesis was a top virtual school administrator. This was a tested project that I had used in its traditional form in a typical school setting, but it has not yet been implemented virtually.

The tools and technology used for the virtual environment were proven tools with the exception of VR technology. VR technology is practical, and VR and mixed reality tools have great potential for K-12 education, but have not been used at my virtual school, EVA, thus there was no feedback on whether the use of VR technology would produce the results desired within the lessons; the author would hope to test that out within a six months period.

Conclusion

Readers may be aware from the study and practical application of the theories mentioned above that Gardner's theory of multiple intelligences (1983, 1991, 1993, & 1999) has allowed one to look at the individual modalities for education and how these may be applied in the classroom. The experiential learning theorists proposed that one must have a cycle of experience and reflection to make it work. The developmental and neurodevelopmental theorists shared various views on cognitive, social and emotional factors, but none of them integrated these theories together with the exception of the pedagogy of constructivism.

To put this project into a framework for constructivist teaching methodology appeared to develop a case in favor of this approach. It was effective in use in virtual education because constructivism, with multi-sensory aspects from Gardner's theory, assisted with development of a curriculum with differentiation possible at many levels. The curriculum could best be developed by using the Understanding by Design (UbD) curriculum development methods, filling in the template provided and beginning from the end goals, through the assessment and observation process, to the development of the lessons. During the assessment and observation, and in the curricular development process, virtual education technology and multiple intelligences theory may be applied to make the curriculum multi-sensory in approach for the

lessons in the unit. It is with this intent that the author will now approach the curriculum unit itself in the coming chapter.

CHAPTER FOUR – CURRICULUM UNIT

Overview of Chapter

This chapter will present a sample multi-sensory-friendly and virtual-tool-rich curriculum unit on near-shore oceans and bays, developed by this author for the field of marine science for the 3-5 grade band. This curriculum was development using the Understanding by Design (Wiggins & McTighe, 2011) curriculum development process and principles of constructivist teaching strategies. These possibilities will address the study question "What are virtual tools and multi-sensory strategies that can be integrated into curriculum development to support the engagement of learners in science in grades 3-5 in virtual learning environments?"

This unit was developed and used for a classroom in a traditional face-to-face educational building during 2009 when the author was co-teaching a unit on Ocean Science. This unit is being translated into the virtual world for use in a future virtual classroom. It approaches the problem of the bay and estuary system and the effects of existing and potential pollution in the Chesapeake Bay of Maryland. This area and the surrounding land and water have many animals and plants that are important to the ecosystem, and these living things may sustain damage as the effects of pollution progress. Along with regional and local governmental and environmental agencies examining and advocating for the improvement of the ecosystem of the Chesapeake Bay area, this author integrates educational resources that may be helpful for the reader of this work and may be used freely by current and future teachers.

Grade Levels: 3-5, Unit: Oceans and Bays, Situation/Background

This is a third through fifth grade project for learning about the near-shore ocean biome and the bays, and specifically about the Chesapeake Bay in Maryland, and the effect of human

activity on it. It is based on The Chesapeake Bay Program, a major federal-state restoration effort. The students completing the unit will be expected to apply what they have learned about identifying and solving problems to develop a local action plan for preserving or restoring a resource in their own communities building off what they learn from The Chesapeake Bay Program. The students completing the unit will gather in a virtual classroom.

To create a multi-sensory aspect to the unit the teacher will have the virtual students use their virtual reality (VR) or augmented reality (AR) headsets, or smartphones with VR/AR viewers (as directed) that are provided by the school at EVA to engage with the application "Chesapeake Bay Unit." The virtual students will also use hands-on tools such as [provide 1 or 2 examples of them]. The projected time for completing the unit is **t**wo hours twice weekly in virtual science class for five weeks, (ten days) with/including a follow up "virtual ocean fair" that will remain online for parents and community.

Connections to Curriculum, Standards, and Learning Goals

This unit had connections to the following content areas: geography, environmental science, biology, marine biology. The unit is designed so that students completing it will meet the following three National Geography Standards:

- **Standard 14: "How human actions modify the physical environment"**
- **Standard 15: "How physical systems affect human systems"**
- **Standard 18: "How to apply geography to interpret the present and plan for the future"**

The learning goal. The goal of this unit is for students to learn about the sea near the shore and about the Chesapeake Bay. Students will learn about efforts to preserve and restore the bay's health.

Student objectives. There are six student objectives for this unit:

- Students will collaborate in the virtual classroom to design a visual online undersea environment and will choose one sea animal to learn about and discuss for their own project.
- Students will be able to teach each other more about the creature they have chosen that lives in the sea.
- Students will be able to discuss sea creatures they have learned about so far and ask one another about their favorites.
- Students will produce a slide and a portfolio for their sea creature, to be presented virtually, and then upload their slide and portfolio to add it to a 3D virtual undersea environment.
- Students will be able to share with each other what they have learned about their favorite sea creature using any number of the sensory-rich methods (determined by the student).
- Students will share their knowledge about the Chesapeake Bay and the science project with their parents, learning coaches and teachers in a virtual group event, and will be assessed by listeners using a presentation rubric.

The rubrics for assessment for the entire project are contained in Appendix D and this author will refer to each within the lesson plan that follows, using an Individual Grading Rubric, an Individual Presentation Rubric, a Team-Peer Group Presentation and Collaboration Rubric.

Action Plan: Focus Questions and Introducing the Unit

Focus questions. *What creatures live in the ocean near the seashore and in the bays? How does human activity affect the sea creatures?*

Introducing the unit. The unit will be introduced by providing them with the following overview:

- On the virtual blackboard or shared VR app, list each child's name and favorite sea creature. Then explain to children that during the next week they are to find out as much as they can about their favorite sea creature so they can tell the class about it at the end of the unit, on Days 8 and 9.
- Suggest to children that they write interesting facts about their sea creature on a PowerPoint document. Children may explore the multiple intelligences.
- Children have various options depending on their self-identified primary intelligence. They may want to make illustrations by hand to scan and upload to their PowerPoint, take or download photographs, or create a video using Vimeo, TeacherTube, or a model or game in Zaption to help them describe their favorite sea creature. It would be necessary to provide safe website suggestions to parents and learning coaches, for the children to look through and choose from.
- In class, examine the biome of the nearshore environment. Brainstorm with children things that might be found on the ocean floor, such as a coral reef, an octopus cave, a sunken ship, a lobster trap. Refer to areas in your virtual 3D classroom as undersea landmarks.
- Begin the exploration of the Chesapeake Bay unit by having the students open the designated AR application on their devices. They take a virtual tour of the Chesapeake Bay area. They then view a presentation together, by application sharing on the Blackboard Collaborate platform (BbC), about pollution from chesapeakebay.net/state regarding pollution and litter.

- Students will also be asked to make three predictions before the start of the unit. They will write their predictions with respect to their animal, the Bay, and the possible effects of pollution, in their new portfolios to begin the unit. These three predictions also function as a pre-assessment for the student.

Day by Day Procedures

Day 1 - procedures. Day 1 will introduce (or review) key terms (*watershed, airshed, ocean, near-shore, estuary, hydrologic, bay, biome, system, ecosystem, pollutant, EPA, modeling, satellite, imaging, simulate, urban, scenario, and phases of study*) with students. Refer them to the website chesapeakebay.net to save and to learn more for this unit.

Move into the study by sharing online the program Google Earth (a program downloadable from google.com website) on the virtual classroom board - opening this and desktop sharing it within the virtual environment. Give them the download bookmark, or website, to download onto their home computers/laptops. This allows them to travel anywhere and to see actual features and buildings (including their own home in most places of the United States). Type in Chesapeake Bay, and lead the class by app sharing to zoom to it on the earth's surface. Zooming in, the class will see the seashore on the Atlantic Ocean, then the Chesapeake Bay and its shape, and will be able to recognize the features around it.

As teacher, ask the students again what a bay is, what an estuary is, and define that a bay is from waters that come into a basin from the ocean and is partially surrounded by land; an estuary is a place that transitions the ocean environment to a freshwater environment. Responses are given by students through the chat box and using their microphones/talk feature in Blackboard Collaborate (BbC). See from the Google Earth views if there are any other sources of water entering the bay from land, usually from a watershed. Then help students define watershed

as water from rain and smaller streams and a river that might feed fresh water into the bay. Share the overview of the watershed, bay and estuary systems. Explain that Washington D.C., our nation's Capital, is near this bay/watershed/estuary system.

Application sharing continuing, go to the following website: https://www.nationalgeographic.org/education/programs/chesapeake-water-quality/ Share also that the website that shows several models of the Chesapeake Bay from chesapeakebay.net is useful. Share that simulations can show the modeling of systems for the bay and estuary and that they show how the bay and estuary works hydrologically. Ask them to look around on the internet and find one other study site or video of the Chesapeake Bay system to share next time. End the session.

Day 2 - procedures. Day 2 starts with synchronous group work. The class will gather online, and review the terms from last class. Converse widely on the Chesapeake Bay system for the first fifteen minutes of virtual class, checking links first, then sending out the link for it in the chat feature of the online blackboard, and opening the link in the teacher browser. While discussing, record a list of these websites shared and open one or two to take a look at them. Laud the students who shared.

Application share in BbC the website for the Chesapeake Bay Foundation: http://www.cbf.org/about-the-bay/maps/ which contains extensive activities and information about the Bay. Then, take the students to the Chesapeake Bay Program website link through the https://www.nationalgeographic.org/education/programs/chesapeake-water-quality/ website and together explore by modeling for them the slide project, by looking up one animal and one plant, and show them how to make a slide or document with information about that item. This will be

an individual assignment that will be graded by the Individual Presentation Rubric (found in Appendix E).

For the individual assignment the students will choose an animal or plant in the Chesapeake Bay area to study and show the effects of pollution, and the preservation or restoration for that animal that might be possible. Push out the Individual Presentation Rubric for the students to save. Provide the students with the following instructions:

- Show them an instruction sheet about what they will do for their chosen animal or plant, and how to upload it into the teacher's dropbox, for the upcoming virtual 3D visual online undersea environment, which will be submitted next week. Push out the instruction sheet, the rubric and the guide for the presentation to be made.
- Each student is first to prepare to make a portfolio of a chosen animal or plant, and will prepare one main slide for the general slideshow for the whole class, about the critters and plants in and around the bay.
- Each child then will develop their portfolio; depending on their intelligence or talent, it can be a Word Document, a PowerPoint set of slides, a song, or a video. It should feature the name of the animal or plant, include drawing using color, and include at least three facts about it.
- The teacher will work next week to compile the individual documents and slides into a class slide show for the virtual 3D underwater show.
- Reinforce verbally and visually the instruction sheet, slide and due date, and portfolio assignment.

Day 3 - procedures. Day 3 will start with data and observations based on tour of Washington, D.C.**.** As the class goes online, have them use their VR/AR devices to take a tour of

Washington D.C. After the tour, talk about Washington D.C. and imagine the number of people that live there. Work with the idea that garbage and pollution, created by human activity, could flood the bay with toxins. In the virtual classroom, share a video or live session of someone's polluting model of the Chesapeake Bay: taking water with food coloring from the side of the bay and pour, to imagine the dirty runoff from a street drain that ran into the river and ended up in the bay.

Ask them to imagine what might happen if that pollution reached the bay. Take and affirm responses. Continue, imaging to use vegetable oil to represent an oil spill, and following the visual demonstration, using Google with the class on the Blackboard Collaborate system screen-sharing, "pollution in Chesapeake Bay" and "oil spills in Chesapeake Bay" on the internet and see what the results might show – photographs especially.

Application share in BbC the website https://www.nationalgeographic.org/education/programs/chesapeake-bay-fieldscope-resources/ and look at how the FieldScope resources work. View how studies can "see" how pollutants have affected the Bay. Then turn to the Chesapeake Bay Water Quality Project, at https://www.nationalgeographic.org/education/programs/chesapeake-water-quality/ and with them, model how to search the site to find more possible animals and plants that have been affected. Students will continue their search and finish their slide to turn in on Day 5. Set them free to work on their portfolios.

Day 4 - procedures. The focus of Day 4 is student portfolio development work. Ask students to record in their student portfolio a description of progress being made related to project their animal or plant. Have them write something about how human activity can affect

the Bay, and whether their animal or plant would be affected by human activity, including pollution. Remind them of the following tasks:

- To turn in their slide for their animal or plant at the next class session.
- To write the conclusion: whether the student's prediction about their animal or plant and its health in the Chesapeake Bay and the pollution that may affect it seems (or is) true or not.
- Push out the worksheet https://www.exploringnature.org/graphics/quiz/rr_rf_chesapeake.pdf which has a number of informational ways to learn using two of the multiple intelligences (verbal/linguistic, visual) to share information and review more about the terms and ecology of the Bay system.
- Ask them to spend the rest of the time that day working offline on their project. Remind them of the deadline the next day to present their Power Point slide.

Day 5 - procedures. During class on Day 5 students will submit into the dropbox their animal or plant slide. Anyone whose dropbox does not contain a slide will receive a reminder call and email that their slide is due today.

Have the students use Google Earth to zoom back to the Chesapeake Bay and look once again at the number of rivers, creeks, ocean access points, estuaries entering the bay. Then have students go to FieldScope and explore aspects of the watershed and estuary, as well as the nearshore environment that have not been explored before. Following this the students will participate in a group assessment. Students can take the quiz and immediately find out the answers to the questions. Give ten minutes for the quiz. This quiz is located online at

http://www.dep.pa.gov/Business/Water/Pennsylvania%E2%80%99s%20Chesapeake%20Bay%20Program%20Office/Pages/Chesapeake-Bay-Quiz.aspx. This will be the activity of the day. Go over it together following the individual completion of the quiz. Share and discuss answers to the questions. Send out an email to the parents and mentors of the students a resource that may help the students complete their portfolios with important information about the Chesapeake Bay and their animal or plant, from http://web.vims.edu/bridge/chesapeake.html?svr=1

Day 6 - procedures. The teacher will have the students record their observations in their individual portfolio about what the sea and bay water looks like when clean and when polluted. Ask them to test the theory that pollution does affect the bay, at home later, using this home experiment: Have them place small pieces of lettuce or other leaf vegetable in cold water with a teaspoon of vegetable oil. Ask them to record their observations in their portfolio about the oily water and see what happens to the leaf after a few minutes in the water. Have them draw conclusions in their portfolio, including a slide or notes on the effect of oil and other pollution on the plants in the Bay.

Define the word *extrapolate.* Ask them to extrapolate what that might do to the animals in the bay when the plants are affected by the pollution, thinking larger not only to their animal or plant but to the larger ecosystem. On the virtual blackboard, model this process by recording some observations, and how to record, draw, or write thoughts about what the oil might do to the plants in the bay if it were coating them. How would that then affect the animals and the bay itself? Draw conclusions by saying, “The effect of the pollution on the Bay and seashore and its plants and animals might be . . .” Ask the students not only to write about this but to debrief in an artistic way. At the end, the exit ticket for the class will be that the students share a drawing they make today, by upload or emailing it to the teacher.

Day 7 - procedures. Day 7 uses Sign-Up Genius and prepares the student for their presentations. The group will begin to prepare their portfolio today to present on Day 8 and Day 9. Have students sign up for a five-minute presentation through Sign-Up Genius created for this purpose. Push out the link for the Sign-Up Genius, and require the students to submit their choices from the beginning of class through the end of class (short online session today). Credit for this day will depend on the submission of the sign-up as a form of exit ticket.

The portfolio submitted after presentations will be the completed project about their animal. All portfolios will be screened for content prior to teacher uploading for the upcoming community project that all can participate in and share with the learning community later, following the conclusion of this unit. The Estuary Fair is the culminating project for the community. All learning coaches and students in the class will be invited and be able to view all portfolios. Anything that is an artistic creation (such as a sculpture, piece of music, drawing, or other visual or sensory art) may be submitted using either a photograph with audio recording, or a video of the final piece. The work will be uploaded into the 3D virtual interactive area, where the students will then with their parents and learning coaches walk through the slides the children have made, placed into the undersea world using VR/AR technology, background music and visuals, and portfolio links. One to two weeks will be required for preparation of and uploading of the portfolios, songs, projects and displays prior to the Estuary Fair. The Research Project Rubric will apply to the Portfolio, found in Appendix E.

Teachers may use the website http://www.chesapeakebay.net/indicatorshome.aspx?menuitem=14871 to find ideas to create virtual stations for an Estuary Fair. At the website, find links to information that can be created

virtually in Power Point, Sway, or another application of the student's choosing that is sharable depending on its characteristics. The day will be spent offline and working on the portfolios after

Day 8 and day 9 - procedures. Days 8 and 9 consist of the presentations by the students. Each student will share their five-minute summary of their portfolio. The summary of their animal presented on these days may include writing, a poem, a piece of artwork, a science project, a handout, a song, a story or video; an app, a game to play, a comic strip, an interview video presentation, or a picture of an experiment about the animal versus the pollutants and their effect on the Bay.

Have students download onto a projection computer three or four videos, sound effects and other materials for presentation about the Bay and its restoration. For example, a publicly available Power Point presentation that could be used is found at http://courses.washington.edu/ocean101/Lex/Lecture20.pdf.

Day 10 - procedures. The class will return to the VR/AR world today. They will tour the Chesapeake Bay again using the Google Earth application, and website https://www.nationalgeographic.org/education/programs/chesapeake-bay-fieldscope-resources/ and look at how the FieldScope resources have applied to their examination of the material in the last five weeks. The teacher will lead them to re-examine the Chesapeake Bay Water Quality Project, talking more about the possibilities for the future as well as the present, at https://www.nationalgeographic.org/education/programs/chesapeake-water-quality/

The teacher will then summarize for the class the Estuary Fair that will occur one to two weeks from the conclusion of the unit. Taking all of the portfolios and slides submitted by the students, he or she will upload them to the class website. The Estuary Fair will summarize the dynamics of the Chesapeake Bay, the animals and plants within and around it, how pollution has

affected the animal, possible conclusions, and projects, and it is an invitational event described below.

The Estuary Fair - Procedures

The Estuary Fair will be a family and school-wide event that will be promoted through the virtual school environment by the 3-5 grade-band teachers for the after the unit has concluded. Teachers may use the http://www.chesapeakebay.net/indicatorshome.aspx?menuitem=14871 website to find ideas to set up their "rooms" online for an Estuary Fair. At the website, one can find links to information that can be created onto large poster board and tri-fold display boards, however they will have to think about the applications in the virtual world. Sound effects and other materials for presentation about the Bay and its restoration may be downloaded and re-uploaded if they are public domain materials. For example, a publicly available Power Point presentation that could be used is found at http://courses.washington.edu/ocean101/Lex/Lecture20.pdf

Finally, the day arrives for the Estuary Fair. The teacher has uploaded each of the PowerPoint Slides to one of the classroom's breakout rooms, and the presentations from each student's portfolio to another breakout room. Participants may virtually wander. The teacher has also created a Microsoft Sway presentation that is downloadable so that each student and family as well as other teachers may examine the presentations, the slides, and the websites referred to both online and using computers, tablets or smartphones, VR and AR tools, at a future time. Links provided within the Sway document as reference, as well as within the live Estuary Fair session will lead the participants to the materials being presented. The virtual classroom opens, and all present enjoy the community to the Estuary Fair!

Considerations for the Teacher

Technical issues. When the internet or platforms used at virtual schools are not available or experience "outages," the leads for the grade band are contacted to send the information out to the parents and students so that substitute times for the lessons are made available for this unit. When issues of student technical equipment, equipment or supplies occur, a hotline is available to students and parents/learning coaches to solve their problems, receive support and find solutions. If the equipment does not function, new equipment is sent out to the student to replace that which does not work correctly. Recordings of the lesson sessions are made available to all students so that they do not miss any of the content.

Engaging the disengaged learner. When the student in the virtual schooling environment will not participate or engage, this problem of engagement will affect the student's progress, attendance, and grades. Most often, if the student will not respond to the teacher's guidance, another layer of support is added. The student is referred by the teacher to the family support team to assist the family and their student in getting back on track. The family support process involves working with families to solve problems, respond to concerns, and help the student through phone calls, emails, online meetings, and structured tracking plans to help the student get back on track. The family support team does not modify the curriculum but works with the overall systemic issues to aid the student in diving back into the material. As engagement returns to more acceptable levels, the parent receives continued support to assure progress is being made, and ideally the student returns to the excitement of learning, along with his or her peers.

Differentiation of the Lesson

Extending the lesson. From the Exploring the Chesapeake: Then and Now website, extend the lesson with website suggestions as noted. Extending the Lesson may include:

1. Take Living Bay Online's Chesapeake Bay Quiz. Students can take the quiz again, and immediately find out the answers to the questions. Share and discuss answers to the questions. Review key terms (*watershed, estuary, ecosystem, pollutant*) with students.
2. Making a game or activity is a great way to teach others about a subject. Have students refer back to the "Did You Know?" facts shown on the Chesapeake Bay Program's site at chesapeake.net. Students may create a puzzle, game, or activity to teach other kids general information about the Chesapeake Bay.
3. To further explore ecosystems, have students examine a small section of a schoolyard, a neighborhood park, or their own yard. Sticks and string can be used to mark off a 4-ft. square area. Be sure students select a spot with plants, rocks, soil, etc. Then have students draw a sketch of everything in their ecosystems, making sure they include all living and nonliving things.
4. Tell students that the Mark Trail comic strip addresses wildlife and ecology issues. Have students view the comic strip (from 2002) that focused on the health of the Chesapeake Bay. After viewing the page and reading the comic, have students create their own comic strip (4–6 panels) illustrating some issue related to the health of the bay and local waters.
5. Spark students' interest by reading one or more of the picture books suggested below.

    The Goose's Tale, by D. Clearman

    Chadwick and the Garplegrungen, by Priscilla Cummings

    Chadwick Forever, by Priscilla Cummings

Sam, the Tale of a Chesapeake Bay Rockfish, by Christina Henry

Where Did All the Water Go?, by Carolyn Stearns

6. Have students use the Chesapeake Bay Program's Coloring Books, which can be downloaded from the Chesapeake Bay Program site. The Chesapeake Bay Program Online Coloring Book features Chessie, a character who teaches about the Chesapeake Bay and its inhabitants.
7. Gyotaku, the Japanese art of fish printing, began long ago and was used by fisherman so they could easily record the types and sizes of fish they caught. Students can try fish printing by trying the activity featured on the Chesapeake Bay Program site.
8. Join teachers participating in the Chesapeake Bay Foundation's Chesapeake Classrooms to share classroom resources, lesson and unit plans, current watershed information, and best practices. The program online is part of National Geographic's EdNet communities for educators.

Adapting the Lesson. For learners that have disabilities affecting any of their senses or their academic level, or who need a more hands-on approach, teachers may have learning coaches work with students on a more tactile level, and may also provide extra instruction sheets in a more step by step manner, often known as a “step sheet” or “checklist.” Video instruction (such as on a TeacherTube video), is often given on how to access each of the materials or websites, step by step. A graphic organizer may be used to assist students in small groups to understand the facets of an ecosystem and how pollution may affect it.

For nonverbal students, or students with cognitive delays, and considering developmental levels of students and their needs, more sensorimotor or sensory rich tools may be used. Virtually, an intervention specialist working with this unit might present it using the musical or

haptic modes, either in VR and AR technologies or in visual and auditory modes by using more video and audio rather than the more linguistic methods.

Storytelling is powerful for adapting material for learners with differences in learning levels. The following is an annotated bibliography of books that can be used with learners of all kinds for this unit, but with special attention to those whose learning levels are lower than the typical grade 3-5 student.

The following suggested nonfiction books are appropriate and recommended for use with young children, and students with lower learning levels that are in grades K-5, during a unit on marine life. These stories may be presented face to face or virtually and are intrinsically multi-sensory.

One Tiny Turtle, by N. Davies

The Sea, by C. Llewellyn

Come to the ocean's edge: A nature cycle book, by L. Pringle

Ocean babies, by D.L. Rose

I am a sea turtle: The life of a green sea turtle, by D. Stille

Additional Resources for Teachers

For resources, here are some good links from the National Geographic website to explore to extend, enrich or modify the lesson:

Alliance for the Chesapeake Bay

Captain John Smith Four Hundred Project

Chesapeake Bay Foundation

Chesapeake Bay Foundation: Expedition Chesapeake

Chesapeake Bay Program

National Geographic Magazine: Saving the Chesapeake

National Geographic News: Grassroots River Cleanup Yields 162 Tons in 3 Hours

National Geographic: EdNet—Chesapeake Classrooms Community

National Geographic: Exploring the Chesapeake—Then and Now

United States Environmental Protection Agency

CHAPTER FIVE: SELF-REFLECTION, FUTURE DEVELOPMENT AND CONCLUSIONS

Overview of Chapter

The question "What are virtual tools and multi-sensory strategies that can be integrated into curriculum development to support the engagement of learners in science in grades 3-5 in virtual learning environments?" is one that was developed in the curriculum unit and in conjunction with the ideas of Gardner, Montessori, Dewey and Piaget and how they related to a multi-sensory education. As an educator, first in the churches since 1995, and later as a part-time educator with science as a specialty on my substitute teaching license from 2010 and forward, the author found the multiple intelligences and the sensory approaches from Gardner (1999) and Montessori (varied) helpful. Chapter Two shared the review of this literature and the summary of big ideas and strategies identified during this capstone. Chapter Three described the how the curriculum was developed. Chapter Four presented the newly developed curriculum unit.

In Chapter Five the author will reflect on what was learned during the capstone process, my current view of myself as a researcher/scholar, accountability, professional ethics, and the implications of the study. This will include recommendations for future research and use of this project, curriculum and thesis.

Self-Reflection

Research for the capstone project and the development of the curriculum unit have been lengthy and productive processes. The review of the literature made connections for this author between the authors reviewed, especially Dewey and Montessori, Piaget and Montessori, and Gardner and Montessori. Multi-sensory education is the pivotal point and all of these researchers

have merit, however Montessori seems to be the most knowledgeable about the importance of multi-sensory education itself. Adding in a variety of virtual reality (VR) and augmented reality (AR) applications and tools, the readily available Google applications, and the research from Pantelidis (2010) most helpful. Selective use of the tools and pedagogy, in conjunction with the Understanding by Design (Ubd) framework (Wiggins & McTighe, 2011) framework was pivotal in enriching the development of the science unit to be presented in a virtual classroom, and its future potential exciting for Engaging Virtual Academy (EVA), a pseudonym for my school, to protect the confidentiality of my participants.

The capstone led to a comprehensive approach that used the ideas present in Gardner's (1999) nine intelligences, the Experiential Learning Cycle (ELC) process presented by Dewey (1938/1997), and the multi-sensory works of Montessori (1912). Virtual education tools and processes including VR and AR, and hands-on, tactile experiences were explored, combined, and envisioned for best practices.

Research took surprising turns in the ever-expanding world of applications, especially in the VR and AR tools and their potential within the virtual education world. Exploration of the limits of the use of VR and AR for younger students was helpful as well, and it is the suggestion of this author that these tools not be provided by the school to younger children. The limits for VR and AR suggested by authors and researchers are 15 minutes or less for children in the middle elementary grades and one hour or less for students in the middle school grades should be respected. If a VR/AR viewer system were provided to students by virtual schools, full disclosure of the limitations and health and safety risks of using the viewer would need to be made for parents and learning coaches, since direct supervision of the student in the virtual educational classroom is not performed by the teachers.

The potential for multi-sensory education in the virtual world is great, whether or not VR and AR technology is used. The suggestions made in the development of this curriculum are broad enough and diverse enough that this curriculum unit could be integrated into either EVA or a traditional or private, face-to-face educational setting.

Sharing the Knowledge

The author will share this curriculum and paper with colleagues at EVA, as well as colleagues at Hamline University for whom this thesis was written. The author also plans to develop a science education blog for the discussion of new ideas and new technologies with colleagues and to invite discussions related to multi-sensory education, the use of VR and AR tools as integrated with other educational tools, and best practices for a fully multi-sensory education, once the degree is earned and the thesis is published. The author realizes the depth and breadth of wisdom and knowledge held by others in the education, science, and technological fields, and would like to continue to learn from others in this way.

In addition, the author plans to connect with or join several organizations discovered during the process of education for the Master's in Education: Natural Science and Environmental Education and to take advantage of educational opportunities related to community education, teacher education, and higher education. Integrating multi-sensory approaches and storytelling, such as those presented by musician and researcher Joseph Bruchac at josephbruchac.com; poet, photographer and phenologist John Caddy at morningearth.org; and biologist and author Konrad Lorenz, may enrich the multi-sensory possibilities and broaden the mind of the teacher and the researcher alike, in the process of education in the science classroom.

Professional Goals

Ongoing professional development in the field of teaching in natural science and environmental education requires continuous growth in order to engage and challenge increasingly diverse students in a rapidly changing world. I will continually seek to strengthen professional skills, knowledge, and perspectives. Prompt reflection about the connections between learning and teaching in multi-sensory educational practice will be a major emphasis on my development. Formulation of future professional development goals will enhance my practice of teaching at the chosen level. While undertaking continuing education I hope to ask mentors to guide, monitor, and assess the progress of my practice toward my goals as they are set.

I hope to obtain an adjunct or part-time position at a higher education teaching level to share experiences and approaches, following this degree. With moderate expertise in Natural Science and Environmental Education, and as I already hold theology degrees (M.Div. and S.T.M.) and have 20 years of teaching experience in the church educational world, if time, energy and financial possibility in life permits I would like to achieve a Doctorate in Ministry exploring the interwoven possibilities in Science and Theology to integrate both teaching and learning toward that goal. Using multi-sensory education in that integrated sphere would be amazing. I would create my objectives to be aimed in that area.

Professional Development and Accountability

For accountability I will continue to uphold professional ethics surrounding my current position, and in my hopes for the future. To assist in development and accountability, as well as continuing educational possibilities, I would like to have a mentor/coach with a creative mind

and heart. I would like to mentor others as well in my areas of expertise; thus, I would undertake a process of both giving and receiving coaching / mentoring.

Coaching is “working alongside” starting colleagues to support their learning. This means supporting/coaching the teacher who is interacting with students and engaging in active learning and reflection about once per month. In order to construct knowledge about instructional practices that improve student learning, coaches provide personalized support based on the goals and identified needs of the teachers they mentor. As I would work with others to share knowledge about my project, curriculum and thesis, I will also work with an experienced coach to facilitate continued learning, to provide or identify additional resources for professional development, and to sustain accountability.

A full criteria for possible professional development for less experienced teachers is found in Appendix G. Mentorship requires full commitment to the self and to the student. To achieve this accountability in the ongoing process of unfolding this kind of education presented in this thesis, the following would be indicators of healthy professional development and accountability in process. Potential indicators of this process are:

- Attend district leadership training opportunities
- Contribute to the growth of colleagues’ instructional expertise in the topic area taught
- Participate in a broad array of educational decisions at all levels of the education system
- Be open to new learning and “aha” moments in sharing knowledge and praxis with others.
- Provide quality learning opportunities based on the school’s strategic plan, district curriculum, and the learning needs of the students
- Maintain an understanding of the developing trends in virtual and science education

- Participate fully in learning conversations
- Set goals for learning conversations with colleagues
- Maintain professional rapport with a personal coach that promotes high quality teaching and learning

The coaching and mentoring relationship is established by both parties and helps to develop accountability and achieve goals that reflect practices and pedagogy. The educator refines, re-adjusts, and problem solves with the coach, and follows a strategy for his/her development in the classroom using best practices, experience, shared ideas, a variety of pedagogy, and teaching theories.

Next Steps

Moving forward my plan is to implement this curriculum unit in an elementary classroom at a virtual school and to apply this curriculum in a traditional classroom, where using up to date technology would be a real joy. There are current gaps in the use of recent technology in the classroom, but the field of virtual education, virtual and augmented reality technology, and smartphone applications is an ever-changing and ever-expanding field. Choosing technology after researching it thoroughly, and finding technologies that serve the purposes of the educational system, district and classroom, advocating for what works and then finding the funding for it, takes continuous discernment. It may be effective within a school system, district and classroom to develop a technology review board or team to face the many challenges and changes technology in the classroom brings.

The bolder task is to continue to seek ways to broaden the multi-sensory approaches to be used in the virtual and face-to-face educational environments and to implement such approaches for the benefit of all students. Students also have tools within their grasp, many having

smartphones, and to invite the use of these phones within the classroom using applications such as previously discussed, could open new doors. In fact, having limited banks of smartphones for checkout in addition to banks of laptops for students in the upper elementary classroom, available for those who do not own smartphones, would be a consideration. Allowing student to use their own devices and harnessing their potential is suggested.

Considering this unit of curriculum, it will be interesting to discover in future classrooms what students think of it, what parts of it they find useful and how that connects to their own personal learning styles and their primary intelligence. Involving the students in interactive live opportunities, such as webcam and GoPro events -- as has been done in some PBS children's shows -- with peers or visiting teachers and scientists in the Chesapeake Bay area, has been suggested.

A suggestion for a pre-unit assessment would be to find a simple survey instrument from Gardner's (1999) resources that each student could take that might identify their primary and secondary intelligences of the nine multiple intelligences Gardner theorized. To do so would help the instructor to differentiate the material more effectively, both in learning level and content, for his or her particular students. In the process of teaching the unit, seeking formative feedback from students would be an excellent idea, as it would help to continue to develop the unit. What worked and what didn't? What other things might have worked? Pick the brains of the students, mine the creativity present there. Also update! Realizing that websites and organizational research is always advancing, many of the links (those that are within this thesis in the curriculum unit contained in Chapter Four) may become obsolete or need updates, in addition to ongoing discovery and addition of new links and resources. It will become an ever-exciting task to sort out these new suggestions and to discuss them, not only from a technological perspective

but from a pedagogical view -- a multi-layered, constructive view -- of multi-sensory education, to watch it develop over time.

Colleague and peer feedback within curriculum development teams, grade band teams, and administrative needs assessment groups, could be pivotal. To find a team of people that would give one another feedback, to reflect together on the benefits, drawbacks, and overall implications of virtual technologies, as well as to assess and discern the needs of the students as related to the present and the future of their education, would be strongly suggested. To continue to review and discuss the value of multi-sensory approaches, and the use of differentiation -- both the details and the overviews and how they relate to one another -- in all content areas but especially in the field of science, would drive the process forward and could produce an ongoing developmental process. To share it as a blog or discussion could be impactful.

Conclusion

My goal for the thesis is that it will spark interest among teachers who have taught in the virtual educational environment, with an ongoing process of learning virtual tools, including AR and VR, platforms, applications and programs that will allow a breadth of planning for science curriculum that will engage and foster excitement in learners. When one begins to explore, to find, and to apply multi-sensory strategies and teaching approaches, one can integrate tools one has never used before. The tools will assist in the development of units of curriculum using new technologies available to enhance and enrich the virtual lesson process.

Using Understanding by Design (UbD) (Wiggins and McTighe, 2011) can assist in the curriculum planning process and in the exploration of multi-sensory teaching and learning. A major objective of this unit has been to enhance the learning experience of students in the virtual educational environment using the multi-sensory ideas of Montessori and other teacher-

researchers. Teachers may integrate the developmental information about the students by using pre-assessments, post-assessments, and projects (such as the Estuary Far) to further differentiate the lesson, and may explore with the students how they self-identify in the multiple intelligences. Working with the students one on one, teachers may be able to foster self-reflection from the students to determine from Gardner's (1999) material how they learn the best. It is important to consider and to harness the student's preferences using the constructive approach. As the student's primary intelligence is identified and taken into consideration in the learning process, and the lessons excite the student, the rewards of the process become clearer. This may help prevent students from getting off track and becoming part of a school-wide academic or engagement referral system.

The impact of science education and new discoveries of how to teach the content effectively and with multi-sensory approaches can make a difference in the lives of students. It can spur forward the gifted as well as the challenged student, open doors for younger and older students alike, place new tools in the hands of the eager learners. It can re-engage the disengaged learners to achieve success by asking them to step into "new worlds and new perspectives," a concept spoken of by Brooks & Brooks (1999) as decentration. also mentioned by Piaget (1976). It is the process of overcoming egocentrism, seeing the world and others in it anew, how we differ from them, examining a curriculum and how it relates to us, how others see it, and how we also differ from it. Montessori (1949) would agree that when the child is allowed to explore with multi-sensory avenues, any one student or groups of students may find themselves immersed in amazement that changes themselves and the world.

From the smallest and most intricate quark to the largest scale discovery of invisible matter in the vast expanses of the universe, when we as learners are able to understand more, ask

more questions, and communicate both our amazement and our confusion, it enriches our humanity and helps us to find both pathway and meaning. To encourage further research in multi-sensory and technological approaches, in science education and related areas, by seeking the guidance of the research “elders” mentioned in this thesis, combined with seeking out new peer-reviewed articles and putting them to work both in the face-to-face and virtual educational environments, may just produce some amazing results.

REFERENCES

Ayres, A. J. (1979). *Sensory integration and the child.* Los Angeles: Western Psychological Services.

Ayres, A. J. (2005). *Sensory integration and the child.* Los Angeles: Western Psychological Services.

Bailenson, J. (2018). *Experience on demand: What virtual reality is, how it works, and what it can do.* Kindle Version. New York, NY: W. W. Norton.

Botts, B. (2006). *Snoezelen: Empirical review of product representation.* (Unpublished doctoral dissertation, later co-published as article). University of West Florida. Pensacola, FL.

Brooks, J. & Brooks, M. (1999). *In search of understanding: The case for constructivist classrooms.* Alexandria, VA: Association for Supervision and Curriculum Development (ASCD).

Bruer, J. (1999). In Search of … Brain-Based Education. *Phi Delta Kappan,* 5, 649-657.

Bowen, R. (2017). *Understanding by design.* Vanderbilt University Center for Teaching. Table for UbD Curriculum Design. Retrieved from https://cft.vanderbilt.edu/understanding-by-design/

Campbell, L., & Campbell, B. (1992). *Teaching and learning through multiple intelligences classroom.* Arlington Heights, IL: IRI/Skylight Training and Intelligences.

Curry, L. (1983). An organization of learning style theory and constructs. Retrieved from ERIC database at https://files.eric.ed.gov/fulltext/ED235185.pdf

Dewey, J. (1938/1997). *Experience and education.* New York, NY: Macmillan Co. Retrieved from http://www.dewey.pragmatism.org/

Edwards, C. & White, H. (1992). Right v. left brain dominance and language skills ability. *Journalism Educator,* 46 (*2*), 32-38.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York, NY: Basic Books Inc.

Gardner, H. (1991) *The unschooled mind: How children think and how schools should teach.* New York, NY: Basic Books Inc.

Gardner, H. Howard (2006). *Changing minds. The art and science of changing our own and other people's minds*. Boston, MA: Harvard Business School Press.

Gardner, H. & Hatch, T. (1993) Finding cognition in the classroom: An expanded view of human intelligence in G. Salomon (ed.) *Distributed cognitions. Psychological and educational considerations,* Cambridge, MA: Cambridge University Press.

Gardner, H. (1999). *Intelligence reframed: Multiple intelligences for the 21st century*. New York, NY: Basic Books.

Gardner, H., & Hatch, T. (1989). Multiple intelligences go to school: Educational implications of the theory of multiple intelligences. *Educational Researcher*, *18*(8), 4-9.

Ginsburg, H. & Opper, S. (1988). *Piaget's theory of intellectual development,* 3rd ed. Englewood Cliffs, NJ: Prentice-Hall.

Inhelder, B. & Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence.* London: Routledge and Kegan Paul.

Kish, C., Sheehan-Holt, J., & Cole, K. (1997). Portfolios in the classroom: A vehicle for developing reflective thinking. *High School Journal,* 80(4/5), 254-260.

Kitchener, R. F. (1986). *Piaget's theory of knowledge: Genetic epistemology & scientific reason*. New Haven, CT: Yale University Press.

Kraft, D., & Sakofs, M. (Eds.). (1988). *The theory of experiential education.* Boulder, CO: Association for Experiential Education.

Kriete, R. (2003). Start the day with community. *Educational Leadership*, 61(1), 68-70.

Lamott, S. (2017). *The very real health dangers of virtual reality*. Online article and video. Accessed at https://www.cnn.com/2017/12/13/health/virtual-reality-vr-dangers-safety/index.html.

Ma, T., Xiao, X., Wee, W., Han, C.Y., Zhou, X. A 3D Virtual Learning System for STEM Education. In book *Virtual, Augmented and Mixed Reality*. Presented at Applications of Virtual and Augmented Reality: 6th International Conference, VAMR 2014, Held as Part of HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014, Proceedings, Part II. Accessed from https://www.researchgate.net/publication/283225503_A_3D_Virtual_Learning_System_for_STEM_Education

Montessori, M. (1912/1964). *The Montessori method*. New York, NY: Schocken Books.

Montessori, M. (1949). *The absorbent mind*. New York, NY: Dell, 1967 edition.

Ojose, B. (2008). Applying Piaget's theory of cognitive development to mathematics instruction. *Mathematics Educator*, 18(1), 26-30.

Pantelidis, V. S. (1993). Virtual reality in the classroom. *Educational Technology*, 33(4), 23-27.

Pantelidis, V. S. (1995). Reasons to use virtual reality in education. *VR in the Schools*, 1(1), 9. Retrieved from http://vr.coe.ecu.edu/vrits/1-1pante.htm

Pantelidis, V. S. (1996). Suggestions on when to use and when not to use virtual reality in education. *VR in the Schools*, 2(1), 18. Retrieved from http://vr.coe.ecu.edu/vrits/2-1Pante.htm

Pantelidis, V. S. (1997). Virtual reality in education and Howard Gardner's Theory of Multiple Intelligences. Retrieved from http://vr.coe.ecu.edu/gardner1.htm

Pantelidis, V. S., & Auld, L. (2002). Teaching virtual reality courses online. CCAI, Journal for the Integrated Study of Artificial Intelligence Cognitive Science and Applied Epistemology, 19(3-4), 87- 132.

Pantelidis, V. S., & Auld, L. (2003). Teaching virtual reality courses online. Global Educator. Retrieved from http://web.archive.org/web/*/http://www.globaled.com/articles/PantelidisVeronica2003.pdf

Pantelidis, V. S. (2010). Themes in science and technology. Special Issue, 59-70. Retrieved from https://files.eric.ed.gov/fulltext/EJ1131313.pdf

Piaget, J. (1970). *Science of education and the psychology of the child*. New York, NY: Viking.

Piaget, J. (1976). *Piaget's Theory.* In Inhelder, B.; Chipman, H.; Zwingmann, C. (eds). Piaget and His School. Springer Study Edition. Springer: Berlin, Heidelberg.

Roschelle, J., Pea, R., Hoadley, C., Gordin D, & Means, B. (2000). Changing how and what children learn in school with computer-based technologies. *Future Child*, 10, 76–101.

Schaps, E. (2003). Creating a school community. *Educational Leadership*, 60(6), 31-33.

Smith, M. (2002, 2008) Howard Gardner and multiple intelligences, in *The encyclopedia of informal education*, http://www.infed.org/mobi/howard-gardner-multiple-intelligences-and-education.

Sterling, D. (2006). A change in seasons: Increasing student observation skills. *Science Scope*, 30(1), 24-29. Retrieved from http://www.nsta.org/main/news/stories/styles

Thompson, C. (2011). Multi-sensory intervention observational research. *International Journal of Special Education*, 26, 202-214. Accessed at https://files.eric.ed.gov/fulltext/EJ921210.pdf

U. S. Department of Education, Office of Educational Technology. (2010). *Transforming American Education: Learning powered by technology.* National Education Technology Plan 2010, U.S. Department of Education Office of Educational Technology: Washington, D.C. Accessed at https://www.ed.gov/sites/default/files/netp2010.pdf

Wiggins, G., & McTighe, J. (1998). *Understanding by design.* Alexandria, VA: Association for Supervision and Curriculum Development (ASCD).

Wiggins, G., & McTighe, J. (2011). *The understanding by design guide to creating high-quality units*. Alexandria, VA: Association for Supervision and Curriculum Development (ASCD).

Winn, W. (1993). A conceptual basis for educational applications of virtual reality (Technical Report TR-93-9). Seattle, Washington: Human Interface Technology Laboratory, University of Washington. Retrieved from http://www.hitl.washington.edu/publications/r-93-9/

Worden, J. M., Hinton, C., & Fischer, K.W. (2011). What does the brain have to do with learning? *Phi Delta Kappan*, 5, 8-13.

Appendix A - Howard Gardner - Multiple Intelligences

Verbal/linguistic intelligence. Verbal/Linguistic intelligence refers to an individual's ability to understand and manipulate words and languages. This includes reading, writing, speaking, and other forms of verbal and written communication. Gardner describes that teachers can enhance their students' verbal/linguistic intelligence by having them keep journals, play word games, and by encouraging discussion (p. 41).

Logical/mathematical. Logical/Mathematical intelligence refers to an individual's ability to do things with data: collect, and organize, analyze and interpret, conclude and predict. Individuals strong in this intelligence see patterns and relationships. These individuals are oriented toward thinking: inductive and deductive logic, numeration, and abstract patterns excite their minds (p. 41).

Visual/spatial. Visual/Spatial intelligence refers to the ability to form and manipulate a mental model. Individuals with strength in this area depend on visual thinking and are very imaginative. Gardner explained that students with this kind of intelligence tend to learn most readily from visual presentations such as movies, pictures, videos, and demonstrations as well as the use of charts, graphs, diagrams, graphic organizers, videotapes, color, art activities, doodling, microscopes and computer graphics software (pp. 41-42).

Bodily/kinesthetic. Bodily/Kinesthetic intelligence refers to people who process information through the sensations they feel in their bodies. These people like to move around, touch the people they are talking to, and act things out. Gardner notes how these students may often express themselves through movement, walking, skipping, running, and dance; all of these are psychomotor activities. Movement can take many forms, and through art can be integrated

using modeling clay or natural materials to sculpt different emotions, thoughts and feelings (p. 42).

Musical. Gardner noted that musical intelligence refers to the ability to understand, create, and interpret musical pitches, timbre, rhythm, and tones and the capability to compose music. Teachers can integrate activities into their lessons that encourage students' musical intelligence by playing music for the class and assigning tasks that involve students creating lyrics about the material being taught. Music is a language in itself, and often musical students have intelligences that may lend themselves to linear structures (other languages, writing, or mathematics) (p. 42).

Interpersonal. Gardner explained interpersonal and intrapersonal intelligences separately, but there is a lot of interplay between the two and they are often grouped together. Interpersonal intelligence is the ability to interpret and respond to the moods, emotions, motivations, and actions of others, requires good communication and interaction skills, and includes the ability show empathy towards the feelings of other individuals, requiring social skills (pp. 42-43).

Intrapersonal. Intrapersonal Intelligence, simply put, is the ability to know oneself. It is an internalized version of interpersonal intelligence and Gardner (1999) suggested that as teachers assign reflective activities, such as journaling to awaken students' intrapersonal intelligence and encourages the intrapersonal learner to form relationships as well. Self-reflection and small group or family participation encourage the development of the student as a person, and the affirmation and communication given personally also may assist the student through the process of learning more quickly and effectively (p. 43).

Naturalistic /environmental. Naturalistic or environmental intelligence is seen in someone who recognizes and classifies plants, animals, and minerals, loves the outdoors and connects with it deeply, and learns from it both by being in it and may be very good at mastering taxonomies. (This intelligence was the eighth added by Gardner (1999) in his revised volume). Gardner describes that students who have this intellectual profile are holistic thinkers who recognize specimens and value the beautiful, novel, or unusual in nature. In addition, students who have this intellectual profile are aware of species such as the flora and fauna around them (p. 52). They may desire to both study and to nurture relationships with plants or animals as they choose their vocation. For example, Charles Darwin and John Muir are people gifted in this way.

Spiritual/Existential. The ninth intelligence, one that has yet to experience full acceptance by educators in the classroom, but which was added by Gardner (1999) in his revised volume, is existential intelligence, which encompasses the ability to pose and ponder questions regarding the existence -- including life and death. This would most often be in the domain of philosophers and religious leaders (p. 59). Responding to questions about life and the meaning of life, wondering about an afterlife, comparing beliefs are activities that require deep thought and support at a global and at an individual level, and have the effect of approaching many of life's questions in a different way are typical of the use of this type of intelligence (p. 66).

Appendix B - Maria Montessori - History and Pedagogy

Maria Montessori was born in 1870, the same year that Italy became a unified nation. Her approach to experiential education was unique. She broke traditional roles between male and female, teacher and student at a very young age. She operated her life as though she could and would affect it. She studied anthropology at university, and then became the first physician licensed in Italy.

In the Montessori Method (1912) Dr. Montessori described her greatest interest in the field of medicine: medical care and education for persons with developmental disabilities. At this time individuals with developmental disabilities were called "mentally deficient." Children labeled as mentally deficient were then brought to hospitals rather than included in the educational system. However, in 1897, Dr. Montessori had revealed that she felt mental deficiency presented ". . . chiefly a pedagogical, rather than mainly a medical, problem" (1912, pp. 32, 35). Students who were mentally deficient began to flourish under her model of education, and her published works changed the Italian government's approach to education for these children.

Montessori proved to the government and to the medical field that all children, including the children she was working with, should not be treated in the hospitals but that they needed to be trained in schools, and she began to develop the "Children's Houses" (1912, pp. 43-44). She began by directing these daycare and educational centers for working class children in one of Rome's worst neighborhoods, and established the first center there (p. 43). Soon, the children began to respond to her teaching methods. She always held them in the highest regard, did not

interrupt them physically or emotionally, did not shout at them, but talked in the quietest voices, and taught her teachers to do likewise.

From the beginning, amazing things happened. Children younger than three and four years old began to read, write, and initiate self-respect. The unconscious absorbent mind (ages 0-3) and the conscious absorbent mind (ages 3-6) were terms defined by Montessori. Dr. Montessori saw in the children an innate ability to absorb the learning culture, and far more than reading and writing. The natural environment she indicated, was their best teacher. Montessori reflected: ". . . it was their excitement for botany, zoology, mathematics, geography, and all with the same ease, [learned] spontaneously, and without getting tired" that thrilled her (The Absorbent Mind, 1967, pp. 56, 68). Montessori (1967) reflected that the child's mind develops like a sponge, naturally, acquiring skills to move and control his or her body and space, taking in information and knowledge from all around him/her first without thought or choice -- the unconscious stage (pp. 69-72) and later shifts to the social, justice, and moral stage of development, or the conscious stage, through intentional focus on experiences. The order of intelligence develops freedom and concentration, the power to choose, and a sense of purpose (pp. 72-84).

Knowing these stages, identifying them and working with the children, Montessori (1912) set about using her time and energy towards perfecting educational processes for these disabled children within the structured, family-like settings. She wanted to use nature, natural materials, relationship, and natural processes hands-on in the school in order to meet the real needs of children. Montessori (1912) developed a broad and tactile system of "works" by which children could learn hands-on; the first structured multi-sensory pedagogy was born (pp. 41-44),

by which the teacher was to allow the child to awaken and proceed into fuller awareness of capabilities, through love, respect, and independent discovery (pp. 37, 43).

Dr. Montessori developed broad educational theory, which ". . . combined ideas of scholar Froebel, anthropologist Giuseppe Sergi, French physicians, Jean Itard and Edouard Seguin, with methods that she had found in medicine, education, and anthropology" (1912, pp. 20-32). In 1900 she began to direct a small school in Rome for disabled youth. The methods she employed were both experimental and miraculous and were both hands-on and sensory-based. Montessori (1912) prioritized the question of the education of the senses, noting that it was of important pedagogical interest" (p. 213) and, ". . . education of the senses is most important from both these points of view. The development of the senses indeed precedes that of superior intellectual activity and the child between three and seven years is in the period of formation" (p. 216).

Montessori (1912) pointed out that the environment should be comfortable for learning, and initiated child-sized tables and chairs, mats, and other learning spaces made for the students. She believed that the learning environment was just as important as the learning itself. Because of this belief her schools were often peaceful, orderly places, were the children valued their space for concentration and the process of learning. Having furniture and equipment of the child's size was a sign of respect and a gift of modeling for the child (pp. 80-84). It was uncommon to treat children with such a high level of respect. Her methods contradicted the educational theories and practice popular during her day. She is sometimes referred to as the one who discovered and revealed the qualities of children different from, and higher than, those usually attributed to them, and to value their spirit (1912, p. 20, pp. 95-100). Her poetic way of describing the child's educational process is shared below (1912, pp. 116-118)

> And such is our duty toward the child: to give a ray of light and to go on our way.
>
> I may liken the effects of these first lessons to the impressions of one who walks quietly, happily, through a wood, alone, and thoughtful, letting his inner life unfold freely. Suddenly, the chime of a distant bell recalls him to himself, and in that awakening he feels more strongly than before the peace and beauty of which he has been but dimly conscious.
>
> To stimulate life,—leaving it then free to develop, to unfold,—herein lies the first task of the educator. In such a delicate task, a great art must suggest the moment, and limit the intervention, in order that we shall arouse no perturbation, cause no deviation, but rather that we shall help the soul which is coming into the fullness of life, and which shall live from its own forces. This art must accompany the scientific method.
>
> When the teacher shall have touched, in this way, soul for soul, each one of her pupils, awakening and inspiring the life within them as if she were an invisible spirit, she will then possess each soul, and a sign, a single word from her shall suffice; for each one will feel her in a living and vital way, will recognize her and will listen to her. There will come a day when the directress herself shall be filled with wonder to see that all the children obey her with gentleness and affection, not only ready, but intent, at a sign from her. They will look toward her who has made them live, and will hope and desire to receive from her, new life. (p. 116)

Montessori also created the “game of silence,” somewhat like meditation, where each child was able to start the day with a sense of peace and focus (p. 117). After just a few times trying the game, they liked it. Through giving children some freedom in a specially prepared environment that was rich in activities, Montessori was able to confirm that many children of 4-6

years are able to learn to read on their own, many will choose to work rather than play most of the time, and many will prefer order and silence. Montessori believed that the potential of the child is comprehensive, revealed only when the complete method of understanding the child's choice, the practical work, the care of others and the environment, and above all the high levels of concentration are achieved.

The process of education, stated Montessori, is “. . . a child who cares deeply about other people and the world, and who works to discover a unique and individual way to contribute” (as cited in Kramer, 1976, p. 216). Montessori often reminded teachers in her course, "When you have solved the problem of controlling the attention of the child, you have solved the entire problem of education" (as cited in Kramer, 1976, p. 217). Her theories of the sensitive periods in the development of a child were new to people at this time, however now they seem to correspond with what we consider to be the “needs” of a child at different stages of their development.

Montessori’s belief in children’s hands-on and multi-sensory education is clear. A whole section of her 1912 work is devoted to detailed work on the use of the senses in education and the detail of each of the senses within the curriculum (pp. 185-218). She took into deep consideration that children learn in a variety of ways, and that they begin the conscious stage of learning with what Piaget will call the sensorimotor stage (see below, the next section) and paved the way for multi-sensory approaches to curriculum used with materials so that the student would synthesize information in ways that last. She concludes her section of this work with the connections between the senses and the spirit:

> Beauty lies in harmony, not in contrast; and harmony is refinement; therefore, there must be a fineness of the senses if we are to appreciate harmony. The

> æsthetic harmony of nature is lost upon him who has coarse senses. The world to him is narrow and barren. In life about us, there exist inexhaustible fonts of æsthetic enjoyment, before which men pass as insensible as the brutes seeking their enjoyment in those sensations which are crude and showy, since they are the only ones accessible to them. (pp. 222-223)

Montessori's work as both a doctor and educator pre-figured medical and educational research on sensory integration, developmental models, and especially in neurodevelopmental theory applied to education.

Appendix C - Jean Piaget - Stages of Cognitive Development

Piaget's earliest stage of cognitive development is the sensorimotor stage (ages 0 to about 2 years). Learning who new persons are, how objects work, and what ideas make the world work, Piaget described in detail descriptions of what children ought to be doing, if they are typical children, during this stage (Osoje, p. 26).

The next stage Piaget listed was the preoperational stage. During the ages of 2 to 7, children think about what they directly perceive through their senses; conservation of volume, length, mass, etc. are not things children could solve at this stage. Sensory input and the way things work is of the greatest interest to them (p. 27).

Concrete operational children (approximately age 7 to age 12), are able to manipulate objects or ideas mentally. Mathematical manipulation of numbers and objects is possible at this stage for typical children. Piaget believed that hands-on learning works the best for concrete learners (p. 27).

Many children can enter the formal operational stage. This stage usually begins around age 12, but may not develop until later; for some teens it is not fully developed and is not reached in some adults. At this stage, Piaget observed that books and materials work well; these fire the imagination and enable readers to identify with characters and vicariously experience situations and emotions; the ability to think abstractly and extrapolate information are part of this stage. Experimentation and synthesis of information is also a characteristic of this stage (p. 28).

Piaget notes that learners can always go back and think and learn from these modes of/at earlier stages; they will always use what they have learned before in sensorimotor ways or

preoperational ways, but during each subsequent developmental stage they will become increasingly free of constraints that would have been imposed on them at the previous stage. Part of the formal operational stage, he reasoned, had to do with perception of abstraction.

As children develop, they progress through stages characterized by unique ways of understanding the world. During the sensorimotor stage, young children develop eye-hand coordination schemes and object permanence. The preoperational stage includes growth of symbolic thought, as evidenced by the increased use of language. During the concrete operational stage, children can perform basic operations such as classification and serial ordering of concrete objects. In the final stage, formal operations, students develop the ability to think abstractly and metacognitively, as well as reason hypothetically. The developmental process employs biophysiological logic.

In general, Inhelder and Piaget (1976) lauds Piaget's construct, and believes that the knowledge of Piaget's stages helps the teacher understand the cognitive development of the child as the teacher plans stage-appropriate activities to keep students learning actively. Its perceived limitations are explained within the text of the paper.

Appendix D - Suggested Rubrics for the Curriculum

Overall Assessment Rubric for Group Work Online

Assessment Items	Excellent Quality (A)	Good Quality (B)	Fair Quality (C)	Poor Quality (D-F)
Group Participation in the Study Process	Student collaborates with other students in the group above and beyond expectation	Student collaborates with other students in the group well, as expected.	Student collaborates with other students in the group not to expectations, but does participate.	Student collaborates with other students in the group in a minimal fashion or not at all.
Individual Understanding of Concepts of Study	Student is able to understand and communicate the concepts presented in the study, above and beyond expectation	Student is able to understand and communicate the concepts presented in the study well, as expected.	Student is able to understand and communicate the concepts presented in the study but not to expectations.	Student is able to understand and communicate the concepts presented in the study, only minimally or not at all.
Development of Group Project	Student is able to work with the group in developing the project in clear ways, above and beyond expectations.	Student is able to work with the group in developing the project in clear ways, well as expected.	Student is able to work with the group in developing the project in clear ways, but not to expectations, or is lax in working with the group.	Student is either not able to work with the group in developing the project in clear ways, or does not contribute to the project at all.
Presentation of Group Project	Student is able to prepare and help present group project above and beyond expectations.	Student is able to prepare and help present group project as expected.	Student is able to prepare and help present group project but not to expectations.	Student is able to prepare and help present group project only minimally or does not help to present the project at all.

Overall Grading	A = Student on average exceeded expectations in the process of learning.	B= Student on average met expectations in the process of learning.	C= Student on average approached expectations in the process of learning.	D-F = Student on average failed to meet expectations in the process of learning.

Individual Teammate Evaluation Rubric

Name:_____
Group #:_____

Rate your teammates' participation within the group project using the rubric below. List your teammates names at the bottom of the rubric along with the points you awarded based on their performance in each of the five categories. An individual's points from group members will be averaged and computed into the final grade for each team member.

Select the statement that best describes your team member and award points accordingly at the bottom of the page next to their name.

Dimension/Task	Needs Improvement (1 pts.)	Average/Acceptable (3 pts.)	Excellent (5 pt.)
1. Individual Participation within Group	My teammate rarely or never contributed to the group project or activities.	My teammate contributed to the group project and activities most of the time.	My teammate always contributed to the group project and activities.
2. Respectful Behavior toward Team Members	My teammate rarely or never encouraged nor supported the ideas and efforts of other team members.	My teammate usually encouraged and supported the ideas and efforts of other team members.	My teammate always encouraged and supported the ideas and efforts of other team members.
3. Sharing of Ideas & Information	My teammate rarely or never offered their ideas and/or findings to the group.	My teammate offered their ideas and finding to the group most of the time.	My teammate always offered their ideas and findings with the other team members.
4. Cooperation & Helping Others	My teammate rarely or never offered to help other group members.	My teammate offered to help other group members most of the time.	My teammate offered to help other group members throughout the project.
5. Organizing Data & Presentation	My teammate is disorganized and offered little to completing the final project.	My teammate works in partnership with others to organize materials and the final project.	My teammate leads the group in organizing the information and producing the final project.

1. Teammate Name_____ Points____+____+____+____+____=____

2. Teammate Name_____ Points____+____+____+____+____=____

3. Teammate Name_____ Points____+____+____+____+____=____

Example: Group Collaboration Rubric

Outcome: Students can collaborate effectively in groups.

When the faculty discussed this outcome, they decided that students should be able to clearly communicate their ideas with others, show respect for others' ideas, and do their fair share of the work.

Group Collaboration Rubric

Dimension	**Rating Category**			
	1 below expectations	**2 needs improvement**	**3 meets expectations**	**4 exceeds expectations**
clearly communicate own ideas				
respect others' ideas				
do fair share of the work				

Overall Grading Rubric Example

Example Grading Rubric

Criterion	Below Standard	Meets Standards	Exceeds Standards	Numeric Grade
Insight	A summary or contains little to no analysis 0–15 pts	Contains a decent analysis 16–20 pts	Contains an in-depth and well-written analysis 21–25 pts	22
Originality	None or only minimal original thoughts included 0–15 pts	Includes original thoughts 16–20 pts	Includes original and well-reasoned thoughts 21–25 pts	18
Length	In required format, is below 15 pages (-1 for each below) 0–15 pts	Meets required format and length 20 pts	Exceeds required length without any fluff 25 pts	25
Grammar and Spelling	Contains many grammar and spelling errors (-2 for each) 0–15 pts	Contains less than 5 minor spelling and grammar errors 20 pts	Contains less than 2 minor spelling and grammar errors. 25 pts	20
Feedback	*Feedback goes here*	*Feedback goes here*	*Feedback goes here*	*Total Grade = 85*

Overall Project Rubric for Teacher

The Rubric

Science Fair Judges Rubric			
Requirement		Possible Points	Points Earned
Scientific Approach a. Purpose and Hypothesis b. Order and logical setup c. Consistent Conclusions	 (10) (10) (5)	25	
Knowledge of Project Area a. Preliminary Research b. Knowledge of related material c. Scopes and limitations	 (5) (5) (5)	15	
Thoroughness a. Sufficient Research b. Data and Observations c. Success of original plan	 (5) (5) (5)	15	
Written Records and Report a. Journal b. Complete Report c. Pages of Report	 (10) (10) (5)	25	
Ingenuity and Creativity a. Clear Explanation b. Use of Materials c. Unique ideas	 (4) (3) (3)	10	
Visual Presentation a. Organized b. Correct placement c. Oral presentation	 (3) (3) (4)	10	
Total		100	

Portfolio and PowerPoint Slide Rubric

Presentation / Poster Rubric

Name:

Date

Skills	4	3	2	1	Score
Use of Time	Student uses their time to work productively and efficiently.	Students uses most of their time to work productively and efficiently.	Student uses some of their time to work productively and efficiently.	Student does not use their time to work productively and efficiently. Student is frequently off task.	
Pictures / Graphics	Pictures and graphics are clear and relevant.	Most pictures and graphics are clear and relevant.	Few of the pictures and graphics are clear and relevant.	The student's pictures are not clear or relevant.	
Required Elements	All of the required elements are clearly visible, organized and well placed.	Most of the required elements are clearly visible, organized and well placed.	Few of the required elements are clearly visible, organized and well placed. May be missing elements.	Missing most or all of the required elements.	
Visual Clarity and Appeal	The project has an excellent design and layout. It is neat and easy to understand the content.	The project has a nice design and layout. It is neat and easy to read.	The project needs improvement in design, layout or neatness.	The project needs significant improvement in design, layout and neatness.	
Content Spelling Grammar Punctuation	The project has excellent spelling, grammar, punctuation, and original content.	The project has 1—2 spelling, grammar, or punctuation errors with original content.	The project has 3-5 spelling, grammar, or punctuation errors with original content.	The project has multiple spelling, grammar, or punctuation errors. Some content is copy and paste or plagiarized.	

Comments:

Total Score:	

20= 100%	19= 95%	18= 90%	17= 85%	16= 80%	15= 75%	14= 70%	13= 65%	12= 60%	11= 55%

Individual Performance in Team Project Rubric

Name:_____
Group #:_____

Rate your teammates' participation within the group project using the rubric below. List your teammates names at the bottom of the rubric along with the points you awarded based on their performance in each of the five categories. An individual's points from group members will be averaged and computed into the final grade for each team member.

Select the statement that best describes your team member and award points accordingly at the bottom of the page next to their name.

Dimension/Task	Needs Improvement (1 pts.)	Average/Acceptable (3 pts.)	Excellent (5 pt.)
1. Individual Participation within Group	My teammate rarely or never contributed to the group project or activities.	My teammate contributed to the group project and activities most of the time.	My teammate always contributed to the group project and activities.
2. Respectful Behavior toward Team Members	My teammate rarely or never encouraged nor supported the ideas and efforts of other team members.	My teammate usually encouraged and supported the ideas and efforts of other team members.	My teammate always encouraged and supported the ideas and efforts of other team members.
3. Sharing of Ideas & Information	My teammate rarely or never offered their ideas and/or findings to the group.	My teammate offered their ideas and finding to the group most of the time.	My teammate always offered their ideas and findings with the other team members.
4. Cooperation & Helping Others	My teammate rarely or never offered to help other group members.	My teammate offered to help other group members most of the time.	My teammate offered to help other group members throughout the project.
5. Organizing Data & Presentation	My teammate is disorganized and offered little to completing the final project.	My teammate works in partnership with others to organize materials and the final project.	My teammate leads the group in organizing the information and producing the final project.

1. Teammate Name_____ Points____+____+____+____+____=____

2. Teammate Name_____ Points____+____+____+____+____=____

3. Teammate Name_____ Points____+____+____+____+____=____

Appendix E - Understanding by Design Template Resource

Stage 1 – Desired Results		
ESTABLISHED GOALS **The enduring understandings and learning goals of the lesson, unit, or course.**	***Transfer***	
	Students will be able to independently use their learning to… **Refers to how students will transfer the knowledge gained from the lesson, unit, or course and apply it outside of the context of the course.**	
	Meaning	
	UNDERSTANDINGS *Students will understand that…* **Refers to the big ideas and specific understandings students will have when the complete the lesson, unit, or course.**	ESSENTIAL QUESTIONS **Refers to the provocative questions that foster inquiry, understanding, and transfer of learning. These questions typically frame the lesson, unit, or course and are often revisited. If students attain the established goals, they should be able to answer the essential question(s).**
	Acquisition	
	Students will know… **Refers to the key knowledge students will acquire from the lesson, unit, or course.**	*Students will be skilled at…* **Refers to the key skills students will acquire from the lesson, unit, or course.**

Stage 2 – Evidence and Assessment	
Evaluative Criteria	**Assessment Evidence**
Refers to the various types of criteria that students will be evaluated on.	PERFORMANCE TASK(S): **Refers to the authentic performance task(s) that students will complete to demonstrate the desired understandings or demonstrate they have attained the goals. The performance task(s) are typically larger assessments that coalesce various concepts and understandings like large projects or papers.**
	OTHER EVIDENCE: **Refers to other types of evidence that will show if students have demonstrated achievement of the desired results. This includes quizzes, tests, homework, etc. This is also a good point to consider incorporating self-assessments and student reflections.**

Stage 3 – Learning Plan
Summary of Key Learning Events and Instruction **This stage encompasses the individual learning activities and instructional strategies that will be employed. This includes lectures, discussions, problem-solving sessions, etc.**

Appendix F - Organization and Research Association Websites

American Field Guide ~ Ocean Habitats: The Intertidal Zone

http://www.pbs.org/americanfieldguide//teachers/oceans/oceans_unit.html

Brings together material from public television stations throughout the US to serve as the centerpieces of lessons for middle and high school classes on a wide variety of topics on the "American Outdoors." The link to "Teacher Resources" leads to lesson plans developed by high school teachers that include learning objectives, materials needed, and instructions for student activities and assessing student learning. Lessons are developed for topics such as animals, plants, ecosystems, earth and space, and public policy. Teaching guides describe specific national and state education standards addressed in each lesson for topics like biological evolution, reproduction and heredity, and diversity and adaptations of organisms.

Canary Database: Animals as Sentinels of Human Environmental Health Hazards

http://canarydatabase.org/

This web site presents a database of peer-reviewed scientific studies using "animals as early warning sentinels of human health hazards." Like canaries in coal mines, animals help researchers discover emerging infectious diseases, like West Nile Virus, SARS, and avian flu. Animals may also provide warning about chemical agents used in terrorism, endocrine disrupting chemicals, and hazards in the home such as lead or pesticide exposure. Curators add citations to the Canary database to "studies of wildlife, companion, and livestock animals, where either the exposure or the health effect could be considered potentially relevant to human health." This site is maintained by staff at the Yale University Occupational and Environmental Medicine Program

and was launched with funding from the National Library of Medicine Information System Grant program.

Environmental Health News

http://www.environmentalhealthnews.org/

Published daily by the non-profit organization, Environmental Health Sciences, Environmental Health News (EHN) provides links to articles published in the world press and accessible on the Web that address topics in environmental health such as chemical contamination, water quality and availability, air pollution, climate change, genetic engineering, and many more. Each issue presents three major columns: “In the News” offers access to breaking stories; “New Science” features “science bytes,” which are brief reports on scientific findings that expand knowledge of relationships among environmental phenomena and human health with links to journal articles and other sources; and “New Reports,” for brief overviews of reports and activities of organizations, typically non-profit, involved with environmental research and human health. EHN is sponsored by the Virginia Organizing Project, a grassroots organization in Charlottesville, VA which is “dedicated to challenging injustice by empowering people in local communities to address issues that affect the quality of their lives.” To that end, editors of EHN present media coverage of new findings in science that have relevance to human or ecosystem health.

Natural Resources Defense Council: Environmental Groups

http://www.nrdc.org/reference/environGroups.asp

This site serves as a directory to organizations whose work focuses on protecting the environment. Links to groups’ web sites are provided with brief annotations about their primary interests (all links worked as of April 17, 2006).

Portal on Carnivore Ecology & Conservation

Orion magazine

http://www.orononline.org

Published since 1982, Orion explores alternative world views that seek to reconnect human culture with the natural world. Articles feature a blend of scientific thinking with art, and issues include powerful photographs and paintings. Each week a feature story is presented on the web site, and many articles are accessible online, some in abridged form.

International GEO Data Portal: Global Environment Outlook

United Nations Environment Programme

http://geodata.grid.unep.ch/

This site provides data for topics such as freshwater, population, forests, emissions, climate, disasters, health, and GDP for 450 economic and ecological variables. Users may download data sets by region and render them in the form of a map, graph, or table. Data is gathered from world agencies such as the Food and Agriculture Organization, World Bank, and World Health Organization. For example, arable land, bird species, consumption of ozone-depleting methyl bromide, motor vehicles in use, or water use as percentage of renewable resources are types of data sets available for download.

U.S. Federal Government Agency Websites

Enviro-Health Links from the National Library of Medicine

http://sis.nlm.nih.gov/enviro/envirohealthlinks.html

Environmental Health and Toxicology is a section of the NLM's Specialized Information Services in which researchers and citizens can find thorough, online information on a range of topics. Reports on lead and arsenic were published in 2005 and are regularly updated. A sample

of broader topics includes biological warfare, hurricanes, environmental justice, and indoor air pollution. Each topic has an overview that links to Web pages that present public health information and background. Other categories of information include details on regulation in the case of toxic chemicals, portals leading to trustworthy websites, searches in PubMed for current literature, and information in Spanish. A related site on Chemical Information (http://sis.nlm.nih.gov/chemical.html) hosts the ChemID databases, which provides information on chemical names, synonyms, structures, and regulatory information.

TOXMAP: Geographic Interpretation of the EPA Toxics Release Inventory

http://toxmap.nlm.nih.gov/toxmap/main/index.jsp

TOXMAP is developed by the National Library of Medicine to enable users to approach data from the Environmental Protection Agency's Toxics Release Inventory (TRI) from a geographic point of view. The TRI program maintains data on toxic chemicals released by industry, which are reported by facilities in keeping with federal law. TOXMAP enables users to analyze chemicals released on site into air, water, or ground using maps of area specified by zip code or on maps supplied by the system. Toxic release data from 1987 makes it possible to depict trends over time.

Educational Institutions' Websites

Institute for the Study of Society and Environment

http://www.isse.ucar.edu/vision.jsp

The Institute for the Study of Society and Environment (ISSE) conducts research to improve understanding of interactions among "climate, environment, and society, and to maximize application of this knowledge in the transition toward sustainability. ISSE pursues multidisciplinary research, furthering goals of the National Center for Atmospheric Research to

examine “atmospheric processes in the context of environmental and societal stresses and to make the resulting knowledge accessible to decision-makers at all levels of government and in all sectors of society.” See the link to “Our Research” for easy access to reports of work in the five broad areas ISSE emphasizes: assessment methods, products, and tools; climate-ecosystem-human interactions; use of scientific information in decision processes; vulnerability, adaptation, thresholds, and resilience; and integrated science and regional applications.

Some Bio-geographers, Evolutionists, and Ecologists: Chrono-Biographical Sketches

http://www.wku.edu/~smithch/chronob/homelist.htm

Science librarian Charles Smith of Western Kentucky University maintains this compilation of biographical sketches for more than one hundred historical figures in the fields of ecology, evolution, and biogeography, from the 17 th century to 1950. Brief biographical summaries are presented with a chronology for each person, and suggested sources for further information are listed with each entry.

Conferences

Connecting the World’s Children with Nature - Working Forum, Nature Education for Young Children

http://www.worldforumfoundation.org/wf/wf2006_nature/

Participants will learn from a team of educators and environmentalists from twenty-five nations about innovative nature education models and collaborations across professions. See the web site for more details on the event and registration.

North American Association for Environmental Education

2004 Conference Proceedings Available Online

http://naaee.org/pages/conferences/2004confproceedings.html

Appendix G - Educational Leadership Development by Criterion

Developed by the University of Washington at Bellingham for the Bellingham School District, this set of criteria helps teachers to examine their own self-development and to undertake continuing education. The author's process is an ongoing portfolio, indicated in *italics*.

CRITERION I. INSTRUCTIONAL SKILLS – The teacher demonstrates, in his or her performance, a competent level of knowledge and skill in designing and conducting an instructional experience.

Indicators:

· Writes and teaches to clear objectives – Utilizes principles of learning – Provides a variety of instructional experiences

· Uses appropriate instructional strategies for students, subject, and goals – Monitors ongoing performance to adjust lessons

· Uses District goals and guide effectively – Demonstrates creativity in the teaching process.

Portfolio – Weekly classroom plan book, syllabus, rubrics, creative projects results, reflection sheet.

CRITERION II. CLASSROOM MANAGEMENT AND ORGANIZATION – The teacher demonstrates, in his or her performance, a competent level of knowledge and skill in organizing the physical and human elements in the educational setting.

Indicators:

· Provides a classroom climate conducive to learning

· Provides a model in demeanor and appearance that does not detract from teaching effectiveness

· Assess individual differences, provides appropriate student grouping and uses appropriate instructional resources to meet individual needs

· Involves students in planning and evaluating their own work where appropriate

Portfolio –Feedback sheets. Grouping reflections. Self-awareness on appearance, demeanor and professionalism, confirmed by mentor and department head. Personal annual evaluation should be included.

CRITERION III. STUDENT DISCIPLINE AND ATTENDANT PROBLEMS – The teacher demonstrates the ability to manage the non-instructional human dynamics in the educational setting.

Indicators:

· Communicates clearly established parameters. Recognizes conditions that lead to problems/ assists students toward self-management, self-discipline, and excitement for learning.

· Responds reasonably to discipline problems – Effectively utilizes the assistance of administrators or support personnel

Portfolio – Conversation sheet with mentor and department head for each situation addressed at the grade level to be taught/in process of being taught.

CRITERION IV. KNOWLEDGE OF SUBJECT MATTER – The teacher demonstrates a depth and breadth of knowledge of theory and content in general education and subject matters specialization(s) appropriate to the grade level.

Indicators:

· Gives evidence of subject matter competency in area(s) to be taught

· Recognizes the relationship between one's subject matter field and other disciplines or subjects

· Keeps abreast of new developments in the subject matter area.

Portfolio – Attendance at local and regional events specific to higher education, natural science, environmental education, and theology including hands-on sensory-rich summer institutes (such as those offered by the Chesapeake Bay Projects). Learning in a specific area always includes continuing education credits and certificates for attendance at same.

CRITERION V. INTEREST IN TEACHING PUPILS – The teacher demonstrates an understanding of and commitment to each pupil, taking into account each individual's unique background and characteristics. The teacher demonstrates enthusiasm for or enjoyment in work with pupils.

Indicators:

· Plans educational experiences based on student unique background and characteristics

· Enjoys working with students

· Provide prompt, meaningful communication among parents

Portfolio – A continuing analysis of students' needs and daily refreshment of feeling and sensing is most appropriate for this – quarterly meetings with coach and mentor might be evidential in this area.

CRITERION VI. PREPARATION AND SCHOLARSHIP – The teacher exhibits, in his or her performance, evidence of having a theoretical background and knowledge of the principles and methods of teaching and a commitment to education as a profession.

Indicators:

· Keeps abreast of current and effective emerging principles of teaching

· Contributes to school and professionalism

· Maintains professional rapport with colleagues, parents, and community

Portfolio – Attendance at local and regional events specific to higher education and learning in a specific area of natural science, environmental education, and theology, including continuing education credits and certificates for attendance at same.

CRITERION VII. EFFORT TOWARD IMPROVEMENT WHEN NEEDED – The teacher demonstrates an awareness of his or her limitations and strengths and demonstrates continued professional growth.

Indicators:

· Participates in Career Development

· Utilizes self-evaluation as a tool for professional growth

· Responds constructively to recommendations

Portfolio – A continuing analysis of students' needs and daily refreshment of feeling and sensing is most appropriate for this – quarterly meetings with coach and mentor might be evidential in this area.

CRITERION VIII. ASSUMES RESPONSIBILITY FOR COMMITTEE, DEPARTMENT, AND CLASSROOM OBLIGATIONS

Indicators:

· Classroom Obligations

· Department Obligations

· Committee Obligations

Portfolio – A continuing analysis of classroom, department, and committees and activities – and refreshment of same at quarterly meetings with coach and mentor might be evidential in this area.