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Toward an improved model of education: Maria Montessori, Karl Popper, and the evolutionary epistemology of human learning

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**Toward an improved model of education:
Maria Montessori,
Karl Popper,
and
the evolutionary epistemology
of
human learning**

**by
Timothy Cauller**

**Presented to the Graduate and Research Committee
of
Lehigh University
in Candidacy for the Degree of
Doctor of Education
in
Curriculum and Instruction**

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Abstract

Although most Americans steadfastly maintain that getting a good education guarantees a better society and opens the door to more rewarding careers, it is debated regularly what the best set of educational priorities and practices that constitute good schooling should be. Sociopolitical considerations of power and control have often driven the agendas of educational reform movements in the United States, and these agendas have typically clustered around adult priorities and ideas of how knowledge should be “transmitted” to children (Cuban, 2003, 2004; Kliebard, 1995, 2002; Perkinson, 1968, 1980, 1984; Tyack & Cuban, 1995). It is asserted in this dissertation that approaches to educational reform should instead be derived from an informed understanding of naturalistic human learning so that curricular structures and pedagogical practices start from children and work backwards in support of their intrinsic curiosity and search for regularities in the world around them.

This paper argues that philosopher Karl Popper’s theory of the acquisition of human knowledge, commonly referred to as an evolutionary epistemology, provides a sound theoretical framework from which to build improved educational systems that complement naturalistic human learning. It is further argued that the Montessori system of early childhood education, first introduced in Rome in 1907 by Italian physician and educator Dr. Maria Montessori, strongly evidences the principles and applied practices of an evolutionary epistemology, thereby potentially explaining Montessori’s subsequent success in educating children across varying cultures and backgrounds worldwide. Drawing on the understandings that a combined Popperian/Montessorian perspective may suggest, the Education-as-Evolutionary Epistemology (EEE) model for educational

reform is then proposed. The EEE model's twelve integrated recommendations present a principled guide for reconceptualizing formal learning environments by addressing three critical areas for future school reform: revised structure and organization of the learning environment, new roles and training for the learning environment's participants, and the design of curricula and assessment to support students' trial-and-error learning processes. It is suggested that future research efforts be directed toward rigorously testing the EEE model's hypotheses in order to further identify and eliminate the model's errors in attempting to solve some of formal education's most vexing problems.

Chapter 1: Re-framing the Rationale for Educational Reform

According to Tyack and Cuban (1995), it has become a truism for Americans that getting a good education is foundational for a successful life and rewarding career. The benefits of a good education, it is thought, extend to maintaining a stable democracy and a healthy national economy. An educated citizenry allows for full participation in the greater body politic and enables Americans to work towards their individual vision of the metaphorical American dream. To be sure, there has always been a wide range of ideas throughout America's history as to what constitutes a "good education" and what life and career qualities qualify as "successful" and "rewarding." The multitude of competing ideas related to education and its role in American society has helped shape an educational system that has evolved in ways that have often made good on the promise of a better life for rising generations of Americans and for a stronger, more prosperous country. However, it is also a truism that if it appears that the goal of making progress towards achieving the American dream is somehow threatened or eroded, the culprits typically first pointed to are America's schools and their collective shortcomings.

In recent decades, the recurring perception that has been prominently discussed and updated for the current era is that the majority of America's youth is critically undereducated and ill prepared for the complex challenges of a 21st century information-based society (see, for example, Gerstner, Semerad, & Doyle, 1994; Perelman, 1992). Indeed, America's educational system is often seen as one that attempts to educate the nation's youth for the current information age by utilizing an industrial era model that conceptualizes schools as "learning factories" (A. Lillard, 2007) while following a school calendar that perfectly fits an agrarian society. The palpable fear for many Americans

seems to be that the United States is losing its ability to keep pace with other countries in an age that features an increasingly intertwined and highly competitive international economy.

Many of these modern fears were made explicit in the National Commission on Excellence's influential 1983 report, *A Nation at Risk*. What seemed particularly relevant at the time was the purported paucity of America's achievements when compared with the alleged educational, industrial, scientific, and technological achievements of other nations. According to Passow (1990), the release of *A Nation at Risk* was a catalyst for extended and extensive activity at both the state and federal levels towards funding educational reforms and tightening standards for academic achievement and teacher quality. Nonetheless, Ripley (2010) recently reported that, despite efforts to decrease average class size over the past three decades to the current 16:1 student-teacher ratio and to increase educational spending per-pupil by an average 123% over the same time period, student performance has shown little, if any improvement.

Buttressing many of Ripley's claims, Provasnik, Gonzales, and Miller (2009) summarized for the federal government the achievement levels of American students of different grades and ages relative to their international counterparts by reporting on the longitudinal results of student performance in reading, mathematics, and science on three international assessments: the Progress in International Reading Literacy Study (PIRLS), the Program for International Student Assessment (PISA), and the Trends in International Mathematics and Science Study (TIMSS). In the PIRLS assessment of reading, American 4th-graders scored above the statistical average of 500 but below 10 of the other 45 participating countries. Additionally, between the 2001 and 2006 administrations of the

PIRLS, no measureable change in the average 4th-grader literacy scores was achieved. Similarly disappointing results were noted in 4th-graders' mathematics achievement, with only somewhat better results achieved by 8th-graders. Mathematics results on the 2006 PISA for 15-year-olds, however, were more troubling, with American students placing 24th out of 29 participating countries and no measureable change in math scores noted between the 2003 and 2006 PISA test administrations. For science results on the TIMSS, the authors reported that American 4th-graders placed 5th internationally, 8th-graders placed 10th, and 15-year-olds placed in the bottom third of the 30 countries who participated in the 2006 PISA administration. The students who scored higher than their United States' counterparts did on these assessments are typically from some of the very countries that are often held up as models for American educational reforms: Chinese Taipei (Taiwan), Korea, Japan, Hong Kong, and Singapore. The authors concluded by faintly praising American student academic performance, stating that "The performance of U.S. students neither leads nor trails the world in reading, mathematics, or science at any grade or age" (p. 45).

Despite the preponderance of statistical data that appear to support the popular notion that America's youth are failing America and that America is failing its youth, it can also be argued that the problem, to the extent that it actually exists, may be more nuanced than is *prima facie* apparent. For one, the comparison may be akin to comparing apples and oranges. Many of the nations that the United States is pejoratively compared with are much smaller in geographic size and population, are mostly ethnically and culturally homogeneous, and are generally unacquainted with assimilating relatively large numbers of immigrants into their societies. The tremendous diversity of American

students –culturally, linguistically, and socioeconomically– may make it less likely that standardized measures of student achievement can fully and fairly capture the American version of “good learning.” In addition, overreliance on standardized testing as a measure of student achievement from which to identify and design needed educational reforms may come at the expense of developing curricula and pedagogy that promote real-world application of knowledge and skills. Knowledge without the creative know-how of what to do with it tends to remain largely inert. Additionally, teaching to the test to achieve higher test scores might satisfy an anxious public; however, it can just as easily be considered a short-term band-aid that patches over other underlying systemic problems that require solutions in their own right to achieve long-term, meaningful curricular reform.

As the debate continues regarding the extent to which America’s youth are or are not sufficiently prepared for the challenges of 21st century life, it may be informative to examine in some detail one highly coordinated approach to education first introduced in Italy a little over a century ago. This approach, the Montessori system of early childhood education, has been commonly observed to be surprisingly effective with students across greatly differing cultures, languages, and socioeconomic backgrounds. This dissertation will further argue that Montessori holds significant promise from both a theoretical and a pedagogical standpoint as a model for reforming American education and for stemming the perceived downward spiral of the American educational system.

Montessori: A Brief Introduction

Originally developed by Italian physician, Dr. Maria Montessori, as a pedagogical treatment for special needs children, Montessori’s dramatic success with this group of

students gave her the impetus to expand her custom designed didactic apparatus and pedagogical techniques to children referred to as displaying “normal” intelligence. She established her first school, the *Casa dei Bambini*, or Children’s House, in Rome in 1907 and embarked on a 50-year career that led her to live and establish other similar schools in numerous countries throughout the world (Kramer, 1988). Although Montessori schools in the United States have never been embraced by the general public to the extent that they have been in other countries such as India or Holland, for example, there still exists a committed group of teachers and former students who have helped maintain a consistent, albeit minor Montessori presence in the greater American educational system.

Some of the reasons behind Montessori’s continued fringe position in the American educational community will be discussed in greater detail in Chapter 3; however, it is not for lack of pedagogical integrity. Although the amount of empirical evidence for Montessori’s effectiveness has trickled into the literature only fairly recently, there have been a few studies that have added credence to the many years of anecdotal evidence of Montessori’s educational robustness. Dohrman (2003) conducted a longitudinal study of two groups of high school students who graduated from the Milwaukee Public School (MPS) system. The first group of students had attended Montessori schools within the MPS system through the 5th grade and had then switched to non-Montessori MPSs. The second MPS group did not attend any Montessori schools. The results showed that the Montessori group of students scored significantly higher in math and science on the American College Testing (ACT) and Wisconsin Knowledge Concepts Examination (WKCE) standardized tests than did the non-Montessori students. Differences between the two groups in English and Social Studies scores were judged

statistically insignificant although noteworthy. The study suggested that the Montessori experience in earlier school years may have a substantive impact on students' acquisition of math and science skills.

Another study that involved a Montessori school that served primarily urban, minority Milwaukee school children was undertaken by Lillard and Else-Quest (2006). The researchers compared cognitive/academic and social/behavioral measures of a 5-year-old Montessori group of students with a similar group of non-Montessori 5-year-olds. Similar groups of 12-year-old Montessori students and non-Montessori students from the same school system were also compared. The authors reported results that suggested that Montessori students exhibited social and academic skills equal to or superior to those of students from other types of schools.

To best appreciate the potential value that the Montessori system of education might possess for informing meaningful future reforms within American schooling, it is first necessary to explore the major historical themes and movements that have competed with each other and, ultimately, contributed to the state of the educational system as it exists in the United States today. As Tyack and Cuban (1995) observed, institutional inertia and accretions of practices over time continue to play as important a role in how schooling is conducted as curricula and pedagogy do. This exploration will be the focus for the remainder of this chapter.

An Historical Analysis of the Sources of Reform Within the American Educational System

The way in which America formally educates its rising generations of children and young adults has grown to become a diverse patchwork of locally determined

systems and educational approaches that represent varied opinions of both what the goals of education should be and how society's resources—human and financial—should be applied (or not) towards meeting these educational goals. This diversity in everything from what is taught, where it is taught, and how it is taught reflects to a large degree the diversity of Americans themselves and the multitude of opinions Americans have regarding what constitutes good schooling (Kliebard, 2002). As a nation that is peopled overwhelmingly by immigrants and descendants of immigrants hailing from countries and cultures around the world with their own unique perspectives on education, this variety should not be surprising. Add to this sociocultural environment a political system that embraces a complex, dynamic interplay between the power of consensus through majority rule and constitutionally guaranteed individual liberties, and it is perhaps even less surprising that the American system of education reflects such a panoply of views and practices for how best to educate the up-and-coming scholars and workers of tomorrow. As Goodlad (1984) pointed out, the penchant in the United States for providing a high degree of local or regional control over school curricula and policies has led to a highly decentralized and fragmented system that often results in a wide spectrum of educational outcomes for students: what high school graduates know and how well they know it often varies considerably from state to state, school district to school district, or even school building to school building.

Some recent developments in the direction of the American educational system have pushed the system towards what uncharacteristically appears to be, at least superficially, a more coordinated or uniform approach. For example, the passage of the *No Child Left Behind* legislation in 2001 with its stipulations mandating achievement

standards and accountability for achieving those standards in all public schools across the nation, has spurred the states to enact minimum standards of their own that their respective schools must meet (Ripley, 2010). Another recent, although seemingly unrelated, development has come from the influence on curricula of textbooks approved for use in “blockbuster” states like Texas and California. These two states, because of their large state populations and numbers of school-age children, have grown to become the two biggest markets for school textbooks in the United States. As Shorto (2010) reported, Texas alone uses a significant portion of its \$22 billion education fund to buy or distribute 48 million textbooks each year. Consequently, textbook publishers have scrambled to produce textbooks that meet the curricular priorities of Texas’ highly politicized state Board of Education. With a “What’s good for Texas is good for America” spirit, as well as a sharp eye towards achieving economies of scale that reduce costs and increase profits, publishers have then successfully promoted their comparatively limited offerings to school districts in other states. Shorto (2010) further claimed that Texas’ outsized role in textbook creation and selection has positioned Texas, along with its overtly agenda-driven Board of Education, to become a nearly *de facto* arbiter of textbook standardization throughout the United States.

These current examples of trends towards greater curricular standardization notwithstanding, Tyack and Cuban (1995) noted that the fragmented character and regional variations of America’s public school system are still very much embedded in the American educational system. However, the authors asserted that two core beliefs regarding schooling can be identified that appear to have united Americans since the colonial era. The first is that “...progress is the rule in public education” (p. 12).

Whatever the defects that may exist in the system and the quality of the graduates it produces, Americans tend to believe that students are making progress educationally and that the country's schools are responsible for this progress. Secondly, "...better schooling [guarantees] a better society" (p. 12). The authors asserted that the American belief in the power of education to create and maintain a better society in the United States is foundational to the motivations behind each era of educational reform. This appears to have been consistently the case regardless of the degree to which the reforms advocated might have threatened to overthrow the educational practices prevailing at the time (Perkinson, 1968).

Progress, of course, is an ephemeral ideal that is open to many definitions. Yet, it is an ideal that Tyack and Cuban (1995) believed gives direction and coherence to proposed reforms so that schooling can adapt to and match each era's "template of progress" (p. 12). To better understand how the templates of progress have evolved, how these templates have contributed historically to the institution of schooling in the United States as it is currently structured, and what types of reforms and motivations for reform should be more seriously considered for addressing further, future improvements to America's educational system, it is useful to first highlight from the literature five influential developments of previous eras' educational practices. These developments include the establishment of the common school model, the humanist agenda, the concept of social efficiency, the child-centered focus of progressive education, and the social meliorism movement. Doing so will help to illuminate from the perspective of a core group of researchers the significant degree to which changes in pedagogical practices throughout America's history have often been tied to changes in school organization and

management and how sociopolitical motivations for reform typically have driven the discussion of what kind of education should be taking place in America's classrooms. No one historical account of the development of the American educational system can necessarily capture all of the system's complex evolution, yet the collective work of Kliebard, Perkinson, Tyack, and Cuban, in particular, provides a compelling description of the interplay of the sociopolitical forces behind the changing directions of the American curriculum. It is from this targeted body of literature that much of the ensuing discussion and analysis will be drawn.

The transition of the one-room schoolhouse to the common school model.

As Perkinson (1980) described, education from the beginning of the colonial era through the post-American Revolution years mostly mirrored that of Europe. Children from families with financial means were educated privately, and the little education that was available for the poor was provided primarily through volunteer institutions like churches. By the beginning of the 19th century, public education for those Americans who actually attended school typically centered around the bucolic one-room schoolhouse in which a teacher, nearly always a female who had had little or no opportunity for formal training, was in charge of educating a group of students of different age ranges and abilities. According to Kliebard (2002), the dates and length of the school year varied annually to accommodate the busiest times of the agricultural seasons but usually consisted of a winter term and summer term of a couple months each. Going to school was generally valued but attendance was often inconsistent. It was not uncommon, for example, for older, more physically able boys to miss entire summer terms because of other priorities on the family farm. The author related how lessons were highly

individualized, consisting primarily of student memorization of specific passages from textbooks brought from home. Students would take turns, one-by-one going up to the teacher's desk to recite memorized passages, hoping to meet with the teacher's approval. This style of education, memorization and recitation, was the norm, commonly thought to facilitate the building of mental discipline and to strengthen the natural abilities of the untrained mind (Kliebard, 1995, 2002).

Kliebard (2002) further noted that teachers changed frequently in this type of educational environment but family textbooks did not. Consequently, it was possible for some students to be directed to recite the same passages from the same textbook as many as five times over five different terms to five different teachers. As might be expected, a room full of students of multiple ages who were seldom involved in any organized, class-wide work and who were not necessarily interested in memorizing portions of an all-too-familiar textbook, might have a tendency to become unruly. As Kliebard concluded, it therefore fell to the classroom teacher from a very early point in America's educational history to take on what became the primary duty of the job—not teaching *per se* but keeping order.

Calls for educational reform that had slowly been building for some time acquired enough momentum by the mid-19th century that it became increasingly apparent that a grand reform of America's educational system was about to unfold. Perkinson (1968) asserted that these reformers—inspired at first by the Jacksonian democrats of the 1820s—espoused a Protestant, republican ideology and a belief that America should fulfill its destiny as “God's country.” As Perkinson (1980) later noted, motivations for this educational movement were not only ideological but also reactionary. Large numbers of

immigrants, Irish and German in particular, had come to the United States in the first half of the 19th century and, with their arrival came, in the eyes of many, worries of social instability. A coalition of reformers, spearheaded by Horace Mann, the soon-to-be “Father of the Common School,” called for the creation of a uniform –or common– school system that was both publically financed and expanded beyond the primary years to include a secondary level (Kliebard, 2002; Perkinson, 1968).

Perkinson (1980) argued that underlying the reformers’ explicit goal of the common school ideal for educating all Americans was an implicit vision of the public school “...as the agency to unify the society, to create social harmony and stability by imposing on all a common set of values, beliefs, and understandings” (p. 109). To the extent that Perkinson’s analysis is correct, it can be inferred that the move to the common school significantly aided the social impetus for the American melting pot to metaphorically move up to the front burner. This large cauldron was fully ready to blend into its simmering soup the first major wave of new, unassimilated immigrants.

According to Kliebard (2002) and Perkinson (1968), concomitant with this call for reform was the gradual establishment of Departments of Education at the state level and the beginning of a professional class of educators and educational administrators who shared many of the same perspectives as Mann did regarding the deficiencies in the educational system. Kliebard noted that, while Horace Mann and his contemporaries might have been motivated by a utopian ideal of what education in a democratic country as singularly great as the United States was considered to be, the growing elite class of educational administrators in state governments had a different set of motivations. It was their belief, as practical as it was arrogant, that teachers and other non-professional

community members of local school boards had neither the training nor the creative ability to design their own curricula without expert direction. Thus, through this dynamic combination of social and governmental forces and others that followed in this formative period between the Civil War and World War I in particular, a number of fundamental educational reforms took shape that, to a large extent, persist to the current day (see also Tyack & Cuban, 1995).

Kliebard (2002) described how one of the first changes to become prevalent in the move towards a common school was the concept of *grading*, or the grouping of students to correspond roughly with students' age and levels of similar ability and achievement. This change in the structure of schooling had a dramatic effect on both curriculum and pedagogy: if students are grouped by grades (also referred to at the time as *forms* or *classes*), then a common description of what students should achieve to be eligible to move on to the next grade needs to be formulated. According to Kliebard, this realization, in turn, led to a decoupling of curriculum from the textbook and allowed traditional notions of curriculum to grow more complex, conceptually expanding beyond the textbook.

A significant pedagogical outcome that resulted from the restructuring of schools around age and achievement levels was the move teachers had to make towards what Kliebard (2002) termed *ensemble teaching*. If the curriculum calls for a common level of achievement that students must meet to move ahead into the next grade, then teachers have to teach to the group as a whole with this common educational goal in mind. Grading of the school system by achievement level had the effect of forcing teachers to teach to the group instead of teaching a differentiated curriculum to each individual

student. For Kliebard, this change served to greatly diminish the central role that individual recitation played as the defining characteristic of what good teaching and good learning should comprise.

A final side effect of these grand reforms described in Kliebard (2002) related to how teachers were employed. Although the profession remained overwhelmingly female and poorly paid, teaching contracts that extended beyond one season's term to as long as two or three years became more prevalent. This helped bring some stability to the profession as well as greater continuity to the curriculum at a time when the need for tracking student progress over longer periods of time became increasingly necessary.

The calls for reforms of America's educational system grew stronger in the latter decades of the 19th century as high schools became more permanently established fixtures in secondary education and the numbers of teenagers enrolling in high schools increased. This increase in student numbers was driven, in part, by America's transition from an agricultural economy to a new economy built on the technological advances that accompanied the Industrial Revolution. Kliebard (1995) pointed to a small but emblematic example of how economic and social forces affected high school enrollment: the invention of the telephone and its subsequent proliferation in urban businesses, in particular, greatly reduced the need for employing human messengers when time sensitive communication between parties was necessary. These quick-on-your-feet messengers –typically teenage boys– could not compete with the speed of the telephone, and now found themselves out of a job. With no job and nothing better to do, many began to enroll in high school in greater numbers. Kliebard (2002) later noted that an even greater influence on increased high school enrollment was the strong uptick in the

numbers of immigrants, male and female, arriving in the United States, many of whom were in their teenage years and ready to engage in the American high school experience. Perkinson (1980) pointed in particular to the period of time from 1890 to 1920 as comprising the second and largest ever wave of immigration into America. In this wave, immigrants from primarily southern, central, and eastern Europe arrived and mostly settled in large cities. These new arrivals to the United States joined an already significant number of Americans who had left rural areas for what they believed were better opportunities in the cities. Together, this group of new urbanites contributed to the common perception of impending social instability and the consequent need for more effective schooling.

The “Committee of Ten” and the humanist agenda.

The concerns of reformers, though, extended beyond just how to absorb larger numbers of students. At issue was the central question of the purpose of high school and how it fit into the broader educational system. This issue was of particular concern to those at the college level because ensuring a qualified pool of applicants to draw upon was essential for the long-term health of American universities (Kliebard, 1995, 2002; Tyack & Cuban, 1995). Perhaps as a consequence, when a blue-ribbon national committee of educators was formed in the 1890s to examine secondary education and make recommendations for further high school reforms, college presidents and professors comprised the majority of the committee’s membership. The “Committee of Ten,” under the leadership of Harvard University’s president Charles Eliot, released its report in 1893, calling for a number of changes that, it was hoped, would bring a sense of order to what

was widely perceived as the disarray of high school curricula (Kliebard, 1995, 2002; Perkinson, 1968; Tyack & Cuban, 1995).

Not surprisingly, considering the backgrounds and educational biases of the committee members, the report emphasized the priority of rigorous intellectual training in subjects drawn primarily from the humanities. According to Kliebard (2002), the report proposed four model programs of study: Classical, Latin-Scientific, Modern Languages, and English, each four years in duration and designed to prepare students for life, in general, and college, in particular. In a concession to frustrated college-bound high school students and those charged with preparing students for post-secondary education, the Committee also recommended streamlining the highly variable range of college admissions criteria that existed into more standardized criteria. This would then give potentially qualified students a greater number of institutions from which to choose (Kliebard, 2002; Tyack & Cuban, 1995).

Not part of the Committee's report, however, were any proposals for including studies in the newer subjects related to business or manual i.e. vocational training. Kliebard (2002) reported that even though this omission left the committee open to subsequent charges from many, including the influential educational reformer John Dewey, that a small, elitist, aristocratic group was covertly attempting to impose a college preparatory curriculum on all high school students in America whether they were headed towards college or not, the Committee's decision was unanimous. As Kliebard (2002) further summarized, it was the Committee's firm belief that there should be no "...curriculum distinction based on probable destination after high school" (p.41). Even though most high schools at the time were located in cities and only 3.5% of the total

high school population actually graduated, with an even smaller percentage enrolling in college, the Committee of Ten strongly felt that a humanist-oriented curriculum for all constituted the best educational preparation for adulthood in a society that was viewed as becoming increasingly complex and interdependent (Tyack & Cuban, 1995). Despite persistent rumblings of discontent from many corners of the educational world, the literature supports the conclusion that the Committee of Ten's report had a great influence on the template of progress in high school education for the next quarter century (Kliebard, 2002; Perkinson, 1968; Tyack & Cuban, 1995).

The “Cardinal Principles” and social efficiency.

In the ebb and flow of reform movements that have come to characterize the alternating influences of many modern educational practices in the United States, a very different yet equally influential national report was released in 1918 that redirected the focus of high school education through the mid-20th century. The National Education Association's (NEA) Commission on the Reorganization of Secondary Education was charged with recommending reforms that would address many of the perceived shortcomings of the Committee of Ten's earlier proposals. It was felt that these reforms were crucial for American high school graduates' ability to succeed and prosper in what had clearly become a modern industrial democracy. Kliebard (2002) characterized this new report, titled “Cardinal Principles of Education,” or Cardinal Principles for short, as a bold elixir designed to remedy the dated academic conservatism of the Committee of Ten by more fully incorporating the curricular needs of a much more diverse student population in the United States. The Cardinal Principles attempted to take into account the multitude of probable career paths available in early 20th century American society by

emphasizing a curriculum that recognized differences in ability among students. The idea was to plan studies around functional outcomes that highlighted those student abilities that were most likely to be utilized in different occupations post-graduation and to guide students towards areas of concentration that would lead them, based on their individual abilities, into specific careers. An example highlighted by Kliebard (1995, 2002) was the field of vocational or manual instruction, previously assiduously avoided by the Committee of Ten, and now prominently featured and poised to grow larger.

In sharp contrast to the Committee of Ten, the Commission that wrote the Cardinal Principles was headed not by a famous university president, but rather by an unknown former high school mathematics teacher from Brooklyn, New York, Clarence Kingsley. Kliebard (2002) reported that, under Kingsley's devoted leadership, the Commission specified what it believed were the seven cardinal educational principles that should undergird American secondary education: health, command of fundamental processes, worthy home membership, vocation, citizenship, worthy use of leisure, and ethical character. These principles were intended to define a curriculum that was much more utilitarian or practical in nature than the Committee of Ten's humanistic goal of development of the intellect.

In subsequent decades, the process of trying to further define how curriculum should be built and justified around these seven goals resulted in an unprecedented expansion of the high school curriculum (Kliebard, 1995, 2002). Kliebard (2002) explained that, while the goals expressed in the Cardinal Principles were purposefully broad enough to politically appease competing constituencies with conflicting viewpoints, they also left the Cardinal Principles' proposals open to excessively broad

interpretations. Except for the “command of fundamental processes” category that included the “3 R’s” of reading, writing, and arithmetic, the other six principles were often considered categories of living. This prompted Kliebard (2002) to state that, “Thus, almost anything that the human imagination could conceive of became fodder for the secondary-school curriculum” (p. 47). In a somewhat perverse testament to the enduring legacy of the Cardinal Principles and their loosening of the curricular reins to exclude almost nothing, Kliebard (2002) further faulted the Commission’s guidelines for greatly contributing to “...one of the most critical problems that American secondary education faces today...the profound absence of purpose, cohesion, and direction caused in part by the uncontrolled proliferation of school subjects” (p. 47).

Progressive education and its child-centered focus.

While many of the curricular reforms proposed in the Cardinal Principles can be viewed as a straightforward attempt to reject the Committee of Ten’s template of progress, it is also true that the ideas underpinning this new “progressive era” philosophy of schooling were not entirely new. Perkinson (1968) asserted that the principles advocated by many of the progressives, as they were commonly referred to, were based on disparate influences, including the French philosopher and author Jean Jacques Rousseau. Rousseau believed that the natural development of children should serve as the ultimate guide for teachers and curricula, hence children should be the primary focus of study before attempts to design a curriculum are made. Perkinson (1968) also stated that Charles Darwin’s theory of evolution proved influential for some educational reformers by inspiring scientists of human development to conceive of children as evolving organisms who could be scientifically analyzed to discover ways in which curricula

should be made compatible with children's unfolding learning processes. Educator and philosopher John Dewey, as well as the influential psychologist G. Stanley Hall, had already argued persuasively for curricula that were more child-centered and proactively took into account innate knowledge, developmental abilities, and the ever-changing interests of children. Additionally, Dewey had embarked on exploring his unique vision for education in his Laboratory School beginning in the 1890s (Kliebard, 2002), and Italian educator Maria Montessori had already introduced to much acclaim her highly successful, child-centered Montessori system of education to American audiences (Kramer, 1988). However, the Cardinal Principles seemed to resonate most with the American public at large through its broad appeal to the idea of social efficiency. As Kliebard (2002) described, this philosophy, which paralleled many of the themes successfully exploited in industrial America, sought to train students for different adult roles by looking carefully at students' abilities and the needs of American industrial society, and then attempting to allocate educational resources as efficiently and productively as possible in training future graduates to find their respective places in society and to keep the economic machinery of America running.

This philosophy of education, when compared to its predecessor from the Committee of Ten, featured what Kliebard (2002) and Perkinson (1968) felt was a watered-down, anything-goes type of curriculum. Yet, this approach to education also had the effect of strengthening the institution of schooling because of American society's growing dependence on education for helping to alleviate many of the social ills of the era. Gradually, the concept of education in America was transformed from that of a socially inspired institution to a governmental one that, ostensibly, had responsibility for

improving American's general welfare as much as it was responsible for educating its citizens. Perkinson (1968) noted that the industrialization of the United States affected family structure and parental roles in some significant ways. Children who used to be socialized primarily at home on the family farm were becoming increasingly socialized instead in educational institutions as adult family members found work away from the farm in factories, often in or around cities. Although this trend took a fairly long time to assert itself, the change in society was an enormous one. As Cremin (1977) observed, this social shift subsumed a founding tenet of education dating to the Colonial era that had asserted the "...absolute centrality of the household in all childhood education" (p. 28). Additionally, large numbers of immigrants from countries with cultures and languages very different from mainstream America and its previous generations of immigrants needed more effort and time to assimilate into their new American culture (Tyack & Cuban, 1995). As alluded to previously, the American school system by this time had become the primary catalyst for the assimilation process.

The social efficiency philosophy of education that the Cardinal Principles espoused seemed to be a very appropriate template of progress for the era, and insightful criticisms from some corners of the educational world notwithstanding, the document inspired a number of successful reforms spread over the next few decades. However, Kliebard (2002) and Perkinson (1968) agreed that it took a seminal moment in the nation's history to crystallize some significant flaws with this approach to public education and to shock the United States out of its curricular complacency. That moment was provided by the Russians and the launch in 1957 of their satellite *Sputnik*. In this instance, an international event triggered a massive re-think of the purpose of education

in America and the ability of the system to produce graduates who were prepared for the competitive geopolitical challenges of the Cold War. With the subsequent passage of the National Defense Education Act in 1958, the pendulum of educational reform swung back to emphasize the importance of the basics. As both authors described, more rigorous academic subjects from the humanist tradition, particularly mathematics, science, and foreign languages, were once again front and center in school curricula. With the passage of a series of other legislative acts over the following seven years, the federal government established and financed a re-emphasis on the total quality of American education in the face of this purported Cold War threat (Kliebard, 1995; Perkinson, 1968). When the 1950s gave way to later decades in the 20th century, however, calls from constituent groups who had historically not been allowed a strong voice in reform discussions, as well as members of a third, distinctly different wave of immigrants, intensified in their efforts to devise more diversified and inclusive curricula. These calls pushed the template of progress in yet new directions as a new era at times noisily unfolded.

Social meliorism as educational reform.

In their review of American educational history, Tyack and Cuban (1995) emphatically stated that, “Educational reforms are intrinsically political in origin” (p. 8). The pivotal changes to school curricula of different reform movements discussed thus far certainly can be seen from this point of view almost as if the protagonists were engaged in an American-style class struggle for power and control. To cite one example from Tyack and Cuban (1995) and Kliebard (1995, 2002), the Cardinal Principles represented a revolt of the common man against the undue influence that the aristocratic, leftover Victorian-era Committee of Ten attempted to wield for its own selfish purposes. The

success of the Cardinal Principles was seen as a triumphant rebellion of a more democratic middle class that was beginning to exercise its collective muscle and challenge the power of the so-called social elite. However, as can be the case in sociopolitical clashes among segments of societies, there usually exist other segments of society besides those of the main protagonists that are under-represented in the discussions, or perhaps not invited to the discussions at all. As Kliebard, (2002) implied, it seems fair to state that changes in educational direction in the United States from the time of the common school movement of the mid-19th century through the post-*Sputnik* era of the mid-20th century had been decided upon largely by white males who were socially empowered, if not also legally empowered, to make decisions of the magnitude seen in American public education. It was as if this proportionately small group of men were supposed to represent the hopes, aspirations, and motivations of all Americans. With this historical perspective in mind, the voices that arose in greater numbers and in more organized ways in the latter decades of the 20th century began to challenge the traditional patterns of educational reform in some forceful ways, seeking to create in American schooling a more equal and just social order (Tyack & Cuban, 1995).

Beginning in the years following the end of World War II, according to Perkinson (1980), a third wave of immigration to America's cities commenced. This time immigrants came primarily from the western hemisphere: the Caribbean region and countries like Puerto Rico and Mexico. Overwhelmingly, these new arrivals were poor, Spanish speaking, and more easily outwardly identified as immigrants by their generally darker skin coloring. This era of reform, however, saw the gradual dissolution of the traditional American melting pot as these new immigrants began to join the chorus of

other disenfranchised Americans who were forming what Perkinson (1980) termed the *new pluralism*.

In this new pluralism, African-Americans, long struggling to be accepted as full members of American society, sought educational equality and greater opportunities to include diversified curricula that accurately portrayed their accomplishments and contributions. Hispanics and other language minority members began to challenge the American melting pot analogy of linguistic and cultural assimilation. Women questioned ingrained assumptions of traditional gender stereotypes that limited career choices, reproductive rights, and economic parity with men. Education and revised school curricula were increasingly seen as crucial elements in solving these historical social ills and forming new, more equitable patterns of interactions across American society. The incubation for what Kliebard (2002) termed this wave of *social reconstructionism* or *social meliorism* in educational reform had begun on a smaller scale a couple decades before but it was now poised to reach into the nooks and crannies of American society in more concerted and novel ways.

While these reforms paralleled the rise of a much greater diversity of constituents in the national educational discourse and greatly affected, as well as continue to affect, educational priorities in American schooling, it should be noted that a number of elements of previous templates of educational progress remained rooted firmly in place. Tyack and Cuban (1995) and Kliebard (2002) contended that, in spite of repeated, vociferous attempts of reform advocates over the decades, no one approach to schooling has ever completely supplanted or eliminated any other approach. Kliebard (2002) aptly observed that, if anything, competing approaches are more often temporarily submerged

than replaced. Recent examples drawn from the latter decades of the 20th century onwards have seen alternately a return to humanist curricula that has re-emphasized academic rigor through federally supported standardization of assessments of academic achievement; an enhanced focus on child-centered education as an outgrowth, in part, of improved understandings of children's developmental stages through advanced research in neurobiology and psychology; and further refinements in social efficiency by differentiating instruction among students based on individual abilities and anticipated adult roles (Bacharach, 1990; Cuban, 1990, 1993; Tyack & Cuban, 1995).

Building a Philosophy of Human Learning

Throughout this unique history and kaleidoscope of reforms and advancements in schooling in the United States, a few common themes seem to present themselves. The first is Kliebard's assertion that the pendulum of history alternating between a couple entrenched, opposed camps of educational reformers is overly simplistic. Kliebard's historical analyses (1992, 1995, 2002) identified four main groups of reformers, each with its unique philosophical perspective: the humanists, the child-centered advocates, the social efficiency reformers, and the social reconstructionists. To be sure, each group has had its eras of primary influence on the template of progress. However, for Kliebard, even at their zenith, none of these reformer groups has been so dominant as to erase the historical accretion of practices and systematic habits of previous movements. That is not to deny the extent of the influence of these disparate reformer groups but rather to fully acknowledge the partial or temporary nature of the changes that were typically realized.

This realization segues into a second conclusion, one posited by Tyack and Cuban (1995) that asserts the primacy of what the authors called the *grammar of schooling*.

Language in all its creative and useful forms utilizes mostly invisible but organizing grammatical or syntactic structural regularities that have evolved over time to aid comprehensibility. For the authors, educational philosophies and practices likewise have evolved over time and have underlying structural regularities that support their effectiveness. Educational reforms imposed from above or from without that ignore the organizing grammatical system of schooling, and which promise to change completely the way that schools, teachers, and the system operate, are doomed to failure. Again, this is not to suggest that reforms are not influential –they are– however, as Tyack and Cuban (1995) asserted, reforms at best tend to coexist only partially and temporarily with the historical inertia of schooling. As Cuban (1990, 1993, 2003, 2004) and Tyack and Cuban (1995) emphasized, the reforms that seem to make the most difference and last the longest are typically the ones that build outward from the inside of the system and fully recognize the controlling power of the grammar of schooling. The potential for the success of a given set of reforms depends to a large extent on taking into account the opinions, practices, and aspirations of all constituents who have daily responsibility for seeing that America’s youth are being provided with an education that meets their particular needs. Only then can society’s new goals for an educated citizenry be achieved.

One further conclusion that bears re-emphasizing is Tyack and Cuban’s (1995) assertion that school reforms are rooted in the politics of power and control. Reformers generally intend for their proposed reforms to be beneficial for students and society alike. However, it is inescapable that the quest for instituting school reforms involves changing the regularized practices of different groups of people and organizational structures, all with varying degrees of ability and willingness to be flexible. As Cuban (1990, 1993,

2003, 2004) has consistently asserted, the politics of power and control involved can extend along a continuum from the broader level of constituencies across school systems, governmental entities, and the general public to the individual level of interaction between teacher and student behind the closed door of the classroom. This multi-level, pan-systemic range of political factions, frictions, and motivations is a major player in the success or failure of any proposed reform. To deny or ignore this fact, according to Tyack and Cuban, is to naively assume that good ideas will be judged as good and enthusiastically implemented solely on their merits.

This discussion of the circuitous route of change and expansion of the American educational system has, thus far, looked at researchers' analyses that have identified many of the sociopolitical underpinnings of reform efforts over America's relatively short history. Yet, it can be argued that a preponderance of the literature devoted to describing and analyzing the history of educational progress in the United States and to proposing future reforms for strengthening educational practices has been written without sufficient attention to another perspective that holds significant promise for reconceptualizing curricular priorities. Missing from much of the academic and national discourse has been a sustained effort to examine the presumed failings and educational challenges that students face from the perspective of what, first and foremost, constitutes real or true learning. Far too often, education is judged as effective, or not, from the vantage point of desired outcomes as defined by adults and by the types of methodology employed to enhance socially preferred, speedier, and greater amounts of the desired, tangible outcomes of student learning (Heinich, 1991; Hill & Roza, 2010). Instead, if an educational system were to be built upon and strengthened for the benefit of all, it is

arguably essential to begin by examining the most fundamental aspects of the cognitive experience of human learning and the accumulation of human knowledge. Attempts to understand and describe a comprehensive process of human learning, to the extent that they succeed, should then potentially be able to inform educational reformers as to how to approach the question of what constitutes effective curricula. Approaches to answering this question, ideally, would then emanate from this informed understanding and result in processes of formal learning that would more closely complement patterns and proclivities of human learning.

The argument just presented is, at base, not entirely new. In many ways, as Kliebard (2002) and Tyack and Cuban (1995) described, a similar argument inspired the child-centered progressives of the late 19th and early 20th century who advocated the value of building formal educational practices around what seemed to be the naturally occurring developmental stages of children. Motivations for further neo-child-centered scientific approaches have perhaps gained even more currency as research into cognitive psychology and neurobiology has progressed in recent decades and illuminated further insights into human cognitive development. However, despite all of these insights and promising avenues of exploration, what has not yet been a prominent, explicit part of the collective conversation in the field of educational reform is the potentially rich connection between modern philosophy's understanding of the development of human learning and educational practices that could be subsequently built to support these philosophical understandings.

It can be argued, of course, that each of the reformers associated with educational reform movements has acted, consciously or unconsciously, with a particular

philosophical point of view and that philosophy plays a role in shaping American curricula. This is perhaps most evident in John Dewey's extensive suggestions for educational reform. Many of Dewey's principles are grounded in ideas common to classical philosophy, particularly Dewey's firm belief in knowledge acquisition through inductive processes associated with the scientific method (Kliebard, 1992, 1995, 2002; Swartz, 1985). Yet, it can also be argued that the problem of learning by induction, a problem that has confronted philosophers since David Hume's 18th century critique, has only recently begun to be solved. These contemporary understandings, specifically informed by the ground-breaking work of philosopher Karl Popper, offer a perspective on human learning that can serve as a framework from which to evaluate previous efforts at educational reform. More importantly, this framework may also serve as a precursor for building a firmer, naturally realistic foundation for an educational approach that transcends the sociopolitical contexts from which the majority of educational reform efforts have thus far been molded.

Statement of Purpose and Dissertation Outline

In this dissertation, the argument will be put forth which posits that learning environments built on the fundamental tenet of Karl Popper's philosophy, typically described as an *evolutionary epistemology*, might support processes of human learning that enable learners to acquire knowledge. This process will be described as an active engagement between humans and their environment that is as vital to human survival as it is to discussions of formal education. The argument will be put forth by first describing and critically analyzing in Chapter 2 of this dissertation the key components of Karl Popper's philosophy, with emphasis given to his conceptualizations of critical fallibilism,

the accumulation of knowledge as a process of error elimination, and the notion of verisimilitude as a system for judging the relative merit of competing theories. Elements of Popper's philosophy that Campbell (1960, 1974, 1997) characterized as an evolutionary epistemology that proceeds in a blind-variation-selective-retention (BVSR) system will also be explained and discussed.

While a comprehensive description of Popper's philosophy in and of itself might be sufficient for extrapolating proposed models of education that support naturalistic human learning, such a discussion would be necessarily lacking if it were not to also closely examine an existing educational system that appears to show strong evidence of supporting an applied evolutionary epistemological framework. Although not formally based on Popper's work, in part because it predates most of Popper's scholarship by nearly a half century, the Montessori system of early childhood education, it will be argued, could provide a representative example of a highly successful evolutionary epistemology applied to classroom learning. Chapter 3 of this dissertation details this part of the discussion by focusing on an explanation of the primary features of the Montessori *prepared environment* and presents an analysis of the extent to which the principles and practices of Montessori could be interpreted from a Popperian perspective. Chapter 4 then presents a model for educational reform based on an applied Popperian/Montessorian approach that includes specific recommendations and principles that cohere with the complex nature of human learning. Chapter 5 identifies some of the potential obstacles that may need to be overcome in order to implement the model's recommendations and concludes by suggesting possible directions for future research.

Chapter 2: Karl Popper's Evolutionary Epistemology as a Potential Answer to the Problem of Induction and the Growth of Knowledge

In this chapter, an explanation and critical analysis of the theoretical pillars supporting Karl Popper's philosophy is presented. Additionally, it is posited that Popper's philosophy has great potential relevance to designing effective curricula in formal learning environments. Although Popper himself did not devote much of his scholarship towards explicating how his philosophical perspectives might be applied to specific educational environments, a few other researchers have considered this idea, and the concluding portion of this chapter introduces some of the representative associated research. Finally, it is posited that, with an informed understanding of Popper's evolutionary epistemology, a Popperian framework can be applied to analyzing a real-world example of an apparently successful comprehensive educational system –the Montessori system of early childhood education. As previously mentioned in Chapter 1, there does not appear to be any evidence that might indicate an explicit connection between the lives or scholarship and practices of Karl Popper and Maria Montessori. However, a careful examination of the unique pedagogical practices of Montessori –to be described in Chapter 3– may lend support to the argument that the Montessori system of early childhood education reflects, to a large extent, a Popperian evolutionary epistemology. Further, this analysis may also provide support for designing other curricula and learning environments that are equally supportive of naturalistic human learning.

Popper's Nascent Career

Born in Austria in 1902 to a law professor and barrister father and an accomplished pianist mother, Karl Popper grew up surrounded by great books, great music, and a rich Viennese culture that fostered great ideas. Popper displayed from a young age a zeal for contemplating answers to philosophical questions concerning society, politics, and epistemology. However, for reasons both personal and practical, Popper did not claim to be a professional philosopher until 1937 when he was nearly 35 years old and ready to emigrate to New Zealand (Popper, 1976). Because of the lack of educational and career opportunities that characterized Austria's disastrous post-World War I economic climate, Popper struggled for a number of years to find ways to advance with his formal education. Partly as a hedge against an uncertain financial future, Popper changed his pre-university career direction and became a cabinet maker's apprentice for two years until he finally realized in 1924 that his propensity for losing himself in deep philosophical thought while working with his hands was not helping him become a better cabinet maker. This realization prompted him to re-direct his career and focus full-time on his academic interests. He eventually was admitted to the University of Vienna, and received his Ph.D. in 1928. Although he was certified to teach elementary and middle school (referred to as *lower secondary*) mathematics, physics, and chemistry, jobs continued to be scarce, so Popper began his professional career as a social worker for neglected children and then later obtained a position as a school teacher of mathematics (Magee, 1973).

In addition to his diverse interests in philosophy, education, and cabinet-making, Popper, acquired a keen interest in classical music –likely positively influenced by his

pianist mother (Popper, 1976). Although he was not particularly gifted as a pianist, Popper did achieve some recognition as an amateur classical composer and musical historian. Popper studied music history at the university in addition to his primary concentration in psychology and methodology, and his musical studies greatly informed Popper's intriguing perspective on the historical evolution of polyphony and harmonic structure in western classical music. Noting certain parallels between the seemingly disparate disciplines of music and philosophy, Popper (1976) credited his comparative studies of Bach and Beethoven, in particular, for positively influencing his philosophical thinking concerning subjectivity and objectivity and their role in epistemology.

Popper (1976) described how the trajectory of his varied career path underwent a dramatic change by 1937 as a result of two important developments. First, Popper had begun to finally attract increased international attention and respect as a philosopher through the publication of his first major work *Logik der Forschung (The Logic of Scientific Discovery)*. This book laid out in detailed form his unique perspectives on the philosophy of science and the growth of human knowledge. The second development, and perhaps of more immediate concern to Popper's well-being, was Popper's worries of potential persecution by the Nazis for his Jewish heritage if Germany were to invade Austria. As Popper (1976) clarified, both of his parents had converted to Christianity and were baptized in the Lutheran church before their children were born; however, Popper was concerned that this fact would be insufficient to protect him and his family. Consequently, Popper sought to emigrate to a country outside of the Nazi's impending sphere of influence and, after an extended stay in England, he accepted his first teaching position in philosophy in 1937 at the University of New Zealand. In hindsight, Popper's

concerns regarding his safety proved prescient because Hitler did invade within a year of Popper's move, and Austria was thrown into the vortex of the nascent Second World War.

Over the course of his long career, Popper wrote extensively not only on the philosophy of science for which he was first recognized but also on the philosophy of sociology, politics, and history. Popper was politically active and engaged as a youth, believing in socialism, and he briefly identified with the Communist movement in Austria –at least until he witnessed a political rally in 1919 that turned violent and resulted in the deaths of a group of Marxist demonstrators (Ormerod, 2009; Popper, 1976). Ultimately, Popper found significant shortcomings with both sociopolitical theories, and he subsequently devoted much of his efforts throughout his career to expanding and applying his ideas of the natural sciences to the social sciences in support of democracy. Popper, in this second important aspect of his career as a philosopher, persuasively argued the logical and moral grounds for establishing and maintaining governments and societies that are both open and free (see Popper, 1944, 1945, for more detailed accounts of his sociopolitical philosophy).

The Philosophy of Science and the Problem of Demarcation

Underlying Popper's theories regarding the advancement of human knowledge was what he saw as the fundamental problem in the philosophy of science: the problem of demarcation, or the differentiation between "true" science and "pseudo" or "non"-science (Berkson & Wettersten, 1984; Ormerod, 2009; Popper, 1976). Popper (1934/1959) emphasized this point by asserting that, "Finding an acceptable criterion of demarcation must be a crucial task for any epistemology which does not accept inductive

logic” (p. 35). Popper’s epistemology, as will be described in this chapter, includes a criterion of demarcation that many find acceptable while clearly evidencing a non-inductivist epistemology. Popper fully accepted Hume’s rejection of the logic of induction and proposed as part of his own solution to the problem of induction an approach often referred to as *critical fallibilism* (Bailey, 2000; Swartz, Perkinson, & Edgerton, 1980) or *critical rationalism* (Miller, 1983; Ormerod, 2009). To better appreciate how these different aspects of Popper’s epistemology fit together, it is useful to first highlight a few related fundamental questions in philosophy that pre-date Popper. The answers to these questions, which a number of influential philosophers through the ages grappled with in trying to sort out what constitutes valid statements regarding human knowledge, are well described by briefly examining three philosophers in particular: Aristotle, Bacon, and Hume.

Aristotle, induction, and the teleological behavior of nature.

“Action for an end is present in things which come to be and are by nature.... It is plain then that nature is a cause, a cause that operates for a purpose” (Aristotle, “Physics”).

Western philosophy owes a great debt to the ancient Greek philosophers, for they laid the foundation upon which a large portion of western thought and scientific investigation has been built. Aristotle (384-322 BCE), a student in Plato’s Academy for 20 years, focused his studies primarily on biology and philosophy, becoming in 342 BCE Alexander the Great’s personal tutor. Benefitting from Alexander’s support, Aristotle founded the Lyceum as an alternative school to the Academy, and he lectured there in his renowned peripatetic style until being driven out of Athens shortly after Alexander’s

death. Aristotle was also a proficient taxonomist, eventually classifying approximately 540 biological species. To this day, Aristotle remains highly influential through his descriptions of logic and the way that scientific inquiry works (Baird & Kaufmann, 2003; Losee, 2001).

Aristotle conceptualized scientific inquiry as a circular process that begins with observations and sense data, and moves to general explanatory principles that are induced from the observations (the “facts”). These inductive generalizations or explanatory principles then provide the basis for deductive statements regarding the original observations. This inductive-deductive circularity always proceeds in this order and forms the core methodology for scientific explanation.

Losee (2001) explained that Aristotle identified two types of inductive statements that serve as general statements induced from particular facts: simple enumeration and direct intuition. Simple enumeration asserts that what is observed as true among several constituents of a group is presumed to be true of the group to which the constituents belong. For example, if one were to observe a number of instances of the flower known as “rose” and note that these observed flowers were red in color and had sharp thorns on their stems, then it follows that, as a general statement, all roses are red and have sharp thorns on their stems.

Direct intuition refers to inductive statements from a trained, experienced observer who has developed sufficient insight as to what is “essential” in sensory experience data. Losee (2001) provided an example drawn from Aristotle’s *Posterior Analytics*: in attempting to induce an explanatory principle for what causes the moon to shine, the trained observer would notice that the bright side of the moon is the side which

faces the sun. This should lead the observer to directly intuit that the moon's light is actually sunlight that is reflected off of the moon's surface.

For Aristotle, deductive statements consist of syllogisms made up of premises and conclusions. These syllogisms state whether a particular class of "A" is either included within or excluded from another particular class of "B." The validity of these assertions is wholly determined by the relationship in form and structure between the premises and the conclusions. Although deductive logic in this view is hampered by the fact that the conclusion cannot say more than what is validly implicit in the premises and, by extension, does not expand knowledge per se, it can illuminate aspects of the premises that may not have been noticed previously (Ladyman, 2002; Swartz, 1980). Further, deductive logic of the Aristotelian sort can be very powerful in the sense of predictive power. A paradigmatic example of the strength of deductive reasoning that Ladyman (2002) delineated is Euclidean geometry. This system of mathematics utilizes a small number of premises, or *axioms*, to deduce a large number of conclusions, or *theorems*, about the properties of geometric figures.

Aristotle also recognized nature as the final arbiter of first principles of a science, claiming that certain self-evident premises cannot be demonstrated or deduced from more basic principles because they reflect relations in nature and could not possibly be false. This assertion provides Aristotelian science with a teleological orientation in that natural acts are explainable in terms of final causes. For example, an explanation of purposeful behavior in nature is Aristotle's contention that flames from a fire leap up from the earth's surface, as opposed to down, because the natural place of fire is at the top of what he considered earth's atmosphere. Because the end-state of fire is existence in the upper

atmosphere, it is fire's natural property for its flames to reach upwards towards the heavens (Ladyman, 2002; Losee, 2001).

Bacon and the practical application of the scientific method.

Aristotle's vision of science and description of the natural world came to serve as the model for scientific research for centuries, undisputedly so for theological and political reasons as well as scientific reasons. Aristotle's precepts were gradually incorporated into Christian theology and the Catholic church's "approved" world view (Ladyman, 2002). It was not until the late Renaissance and the dawning of the scientific revolution that Aristotelian philosophy came under severe criticism, most famously from the efforts and writings of British philosopher Sir Francis Bacon (1561-1626). Trained as a lawyer and possessing a facile literary ability, Bacon advanced his position as a government official under King James I in a series of increasingly prestigious positions. That is, until he was caught taking bribes for favorable treatment from defendants whose cases were brought before him and was subsequently banished from public life by the House of Lords (Losee, 2001). Notwithstanding this fall from grace, Bacon published in 1620 his *Novum Organum* in which he argued for a scientific methodology that would replace Aristotle's science with one more firmly grounded in empiricism and the amassing of observed data from which to build valid conclusions.

Credited with originating the famous aphorism, "Knowledge is power," Bacon disagreed with the notion of knowledge as an end in itself as it was for Aristotle. Instead, Bacon advocated the practical application of scientific knowledge as a tool for improving the human condition (Losee, 2001; Perkinson, 1984). Like Aristotle, Bacon firmly believed in the inductive process but identified what were to him significant flaws in

Aristotle's methodology. Specifically, Bacon felt that a more systematic method for collecting data was needed and that Aristotle was guilty of too quickly generalizing from explanatory principles based on too few observations. Bacon also found fault with Aristotle's inductive method of simple enumeration, stating that simple enumeration increased the possibility of deriving false conclusions if negative instances of a particular observation were encountered and not properly accounted for (Ladyman, 2002; Losee, 2001).

According to Ladyman (2002) and Losee (2001), Bacon's proposed solution was to, first, suggest that the human scientist purge all preconceived theories from the mind. To understand nature is to let nature reveal its secrets, and this is best accomplished by a neutral, unbiased observer who impartially collects observational data. Secondly, as the data are amassed, inductions should be gradual (not overly hasty), and should build a progressive hierarchy based on the observations that ascend from lower generalizability (statements that are specific to the observed phenomenon) to greater generalizability (statements that extend beyond the observed phenomenon). These generalizations at the top of Bacon's hierarchy were called *forms*, and these forms represented concrete, immediate causes. Bacon contrasted his forms with Aristotle's final, or teleological, causes that were deduced through direct intuition. Bacon asserted that teleological reasoning could be utilized in explaining the goal-directed behavior of humans but that attributing purposeful behavior to natural acts in the pursuit of explaining final causes was misguided (Berkson & Wettersten, 1984; Ladyman, 2002; Losee, 2001).

The third major correction to the Aristotelian method that Bacon proposed was the introduction of a method for distinguishing essential correlations from accidental ones

and, subsequently, weeding out the accidental correlations. Bacon's *tables* were developed and formed part of his methodology for more accurately identifying essential correlations. The advantage claimed for this methodological feature was that it allowed for induction by elimination – those deductive hypotheses that are incompatible with the facts can, and should, be rejected (Berkson & Wettersten, 1984; Losee, 2001).

As summarized by both Ladyman (2002) and Losee (2001), Bacon argued for a major revision of Aristotelian methodology to one that prominently featured careful scientific experimentation and inferences from nature's facts. It is in this respect that Bacon has proven most influential. However, Bacon's condemnation of Aristotle, which was at times quite virulent, was characterized by Losee (2001) as nothing more than "moral outrage" (p. 61) and not the wholesale overthrow of Aristotelian metaphysics that Bacon claimed. Fundamentally, both philosophers shared a similar metaphysics through their commitment to induction as providing the grounds for valid scientific statements. It would take another 200 years until the time of philosopher David Hume to fully expose the fatal flaws of the accepted inductivist metaphysics and to cast doubt on the warrant for deriving norms from facts.

Hume and the illogical logic of induction.

Scottish-born David Hume (1711-1776) entered the University of Edinburgh at the age of 12, headed towards a degree in law. However, against his family's wishes, he dropped out of school at age 18 before graduating, resolute in his decision to become a philosopher. His first book on philosophy was a resounding popular failure but he continued writing and developing his theories while holding a variety of unrelated positions, including tutor to a mad marquee, secretary to a general, and librarian to an

Edinburgh society (from which he was eventually fired for not removing books from the collection that members of the society had deemed obscene). Hume's application to two different universities in Scotland met with rejection, most likely because of his avowed anti-religious views. However, Hume did achieve a large measure of renown in Parisian intellectual society for his philosophical prowess and personal wit while working as secretary for the British ambassador to France (Baird & Kaufmann, 2003; Losee, 2001).

Building on the themes of Locke (1632-1704), Berkeley (1685-1753), and other British empiricist philosophers, Hume extended and made more consistent Locke's approach, in particular, that questioned the possibility of obtaining a necessary knowledge of nature. According to Ladyman (2002), Hume's objections were based on three premises. The first premise was his assertion that knowledge can be parsed and divided into one of two mutually exclusive categories: relations of ideas or matters of fact. Relations of ideas refers to those ideas in which the content is confined to concepts or ideas. These kinds of statements are specific types of conceptual truths in which the predicate is already entailed, by definition, by the subject. Examples of this are linguistic statements such as "Bachelors are unmarried males" or "Horses are animals." A representative mathematical statement could be, "The sum of the internal angles of a triangle is 180 degrees." Matters of fact extend beyond concepts or ideas and furnish information about the world as the world really is. Examples of matter-of-fact statements could include "Snow is white," "Paris is the capital of France," or "Metals expand when heated" (Ladyman, 2002).

Hume's second premise was that human knowledge of matters of fact is obtained entirely through the senses. For Baird and Kaufman (2003) and Losee (2001), this

premise firmly aligned Hume with the British empiricist view that, contrary to Descartes' (1596-1650) assertions, there is no *a priori* or innate knowledge of matters of fact –all conceptions of God and the world come in through the senses. This premise extends to even the most abstract of notions such as the idea of “Good.” Hume fully agreed with the Lockean notion of the mind as a *tabula rasa*, or blank slate, passively waiting to be written upon by the world and those who inhabit it.

Thirdly, Hume believed that developing a necessary knowledge of nature must be preceded by the development of knowledge of a necessary connectedness of events (Baird & Kaufman, 2003). Knowing nature and developing an understanding of its laws occurs through observations of nature and the process of noting recurring patterns from which to induce various laws of nature. However, before these laws can be induced, there first needs to be the understanding that there is a customary pattern of connections among the occurrences being observed. Making note of what Hume called these *customary conjunctions* of seemingly related occurrences is the necessary first step in attempting to establish a necessary knowledge of nature. Hume's further explorations of this third premise, particularly as they related to the idea of cause and effect, led him to a revolutionary description of the inductive process and a series of conclusions that continue to be both influential and controversial to the current day (Baird & Kaufman, 2003; Ladyman, 2002; Losee, 2001; Swartz, 1980).

Hume asserted that both relations of ideas and matters of fact are normative knowledge, meaning that truthfulness or falsity can be determined; however, this determination is proven in different ways. Relations of ideas can be proven deductively independently of empirical evidence through an appeal to *reductio ad absurdum*. This

argument demonstrates how the negative of a proposition implies a contradiction, thereby proving the original proposition true. Further, Hume believed that certain statements regarding relations of ideas are necessary truths. The previous example from geometry that declares the sum of the internal angles of a triangle to be 180 degrees highlights this point –to affirm the axioms and deny the theorem, for Hume, would be contradictory. On the other hand, statements regarding matters of fact, according to Hume, are always contingently true or as likely to be considered true as potentially considered false. However, reasoning alone is insufficient for deriving normativity. Because matters of fact are not logically related and can only be perceived through the senses, an appeal to empirical evidence, therefore, must be made (Berkson & Wettersten, 1984; Ladyman, 2002; Losee, 2001).

Hume’s appeal to empirical knowledge is predicated on his argument that this type of knowledge necessarily depends on discovering a sequence of events and describing the causal relationship that exists as a connection of ideas that otherwise have no logical relation. This, in Hume’s view, is the basis for induction. By carefully understanding the natural associations among ideas, particularly as they relate to cause and effect, warrant for the inductive process of building knowledge of the world can be determined.

Hume noted that, in describing causation, three different principles can be involved: resemblance, contiguity (of time and space), or cause and effect. Causation centers on the experience of constant conjunction; to declare that “A causes B” means nothing more than that “A” is constantly conjoined with the experiential perception of “B” (Baird & Kaufmann, 2003; Berkson & Wettersten, 1984; Ladyman, 2002). As found

in Baird & Kaufmann (2003), Hume (1748) stated that, “...after the constant conjunction of two objects—heat and flame, for instance, weight and solidity—we are determined by custom alone to expect the one from the appearance of the other. ...All inferences from experience, therefore, are effects of custom, not of reasoning. Custom, then, is the great guide of human life. It is the principle alone which renders our experience useful to us, and makes us expect, for the future, a similar train of events with those that have appeared in the past” (pp. 733-734).

Ladyman (2002) summarized what is referred to as the Humean analysis of causation as follows:

1. Events of type A preceded events of type B in time
2. Events of type A are constantly conjoined in our experience with events of type B
3. Events of type A are spatio-temporally contiguous with events of type B
4. Events of type A lead to the expectation that events of type B will follow (pp. 36-37)

It is important to emphasize the defining characteristic in this analysis that the fourth statement makes explicit. The development of an expectation that events of type B will follow from events of type A implies a prediction about the future. Such a prediction assumes a tacit commitment to the idea of a uniformity of natural phenomena. In other words, it assumes that the future will resemble the past. However, it was Hume’s conviction that no such guarantee exists. He asserted that human knowledge does not extend to recognizing necessary or causal connections among events. In fact, Hume

stated, there is no warrant for assuming any necessary connection in nature. Instead, all that can be accurately asserted is the experience of the constant conjunction of events (Baird & Kaufman, 2003).

If the Humean analysis of causation is correct, then it metaphorically has the effect of driving a stake through the heart of nearly two millennia of assumptions about induction as a logical system for the scientific accumulation of knowledge. If induction presumes causal relationships, and cause and effect descriptions lead to statements about future events that cannot be justified because there is no guarantee that the future will resemble the past, then there is no valid justification for induction. The canonical example of this logical dichotomy is the famous generalization that “All swans are white.” Numerous observations in Europe held this statement to be true. That is, as Ladyman (2002) described, only until a black swan was discovered in Australia and the statement that all swans are white was shown to be inaccurate. The point to be made is that, despite n confirmations of a sense-derived inductive statement (number of white swans seen, for example), it is only necessary to observe one counter-example (the sighting of a black swan) to negate the entire inductive statement. This problem of induction, the notion that norms cannot be derived from facts, led Hume to conclude that universal laws of nature, although perhaps inevitable, can never be proven if sensory experience is the only source of knowledge. Therefore, according to Berkson and Wettersten (1984), Hume argued that the only type of inductive statement that is logically valid is one that limits itself to provisionally describing a given set of observations as true up to now.

The logical fallacy inherent in the inductive process of scientific inquiry that Hume pointed to was sufficient to mortally wound the theory by bringing into question the rational support for scientific knowledge. However, induction still was extremely useful as a common sense tool and too valuable in this regard to ignore. Lipton (1998) succinctly made this point by stating that, “According to Hume, we are addicted to the practice of induction” (p. 416). As Baird and Kaufmann (2003) related, Hume, despite his skepticism of inductive inferences from cause and effect relationships, still believed that it would not be wise to jump out of a window. Hume could not support induction as a logically valid theory of scientific knowledge building but he was willing to concede that, although unjustifiable, it could be considered true as a psychological theory grounded in the human tendency towards habit formation.

Popper’s Critical Fallibilism as a Potential Solution to the Problem of Induction

Solving the problem of induction that Hume presented has proven to be a challenging task. A number of responses have been proposed over the past few centuries that have attempted to reconcile, for example, the common sense warrant for learning from experience with the irrational logic of drawing inductive inferences. Kant (1724-1804) reformulated Hume’s distinction between matters of fact and relations of ideas into one that differentiated between synthetic statements, which provide the empirical content of theories, and analytic statements, in which the meanings of the terms of the statements determine the normativity of the statements. Whereas, for Hume, empirical content could only be derived through the senses, Kant famously, and controversially, argued for *a priori* knowledge of certain empirical principles or truths. Other philosophers, most notably the Logical Positivists of the Vienna Circle, rejected Kant’s belief in the synthetic

a priori and took a more anti-psychologist stance. Two members of the Logical Positivists in particular, Reichenbach and Carnap, attempted to justify inductive inferences using mathematics and probability theory to calculate the extent to which inductively derived statements could be confirmed (Ladyman, 2002).

More recent related attempts that utilize Bayesian statistics have described inductive inferences as probability statements that express degrees of belief towards the confirmation of a given theory. Other proposed solutions have focused on refining aspects of Hume's analysis to show that induction can be inductively justified, similar to the notion that deduction can be deductively justified. Still other arguments have proposed revising induction into a process of abduction in which explanatory principles serve as an inference to the best explanation (Ladyman, 2002). Alternatively, Karl Popper's radical response to the problem of induction stands out not only for its agreement with Hume that induction cannot be logically justified but also because it completely rejects any appeal to inductive logic.

As Hume accurately noted, repeated confirming observations of an event, whether two or two million observations, do not establish a universal law or truth. Therefore, universal theories cannot be conclusively verified. Further, to rely on induction as a methodology for determining explanatory principles or for justifying scientific theories is to perpetuate a false criterion for the demarcation between science and non-science (Ormerod, 2009). As Magee (1973) summarized, "The popular notion that the sciences are bodies of established fact is entirely mistaken...it is a profound mistake to try to do what scientists and philosophers have almost always tried to do, namely prove the truth of a theory, or justify our belief in a theory, since this is to attempt the logically

impossible” (p. 19). Instead, Popper believed that “...scientific theories always remain hypotheses or conjectures ...” (Popper, 1976, p. 79) because they are always capable of being falsified.

To Popper, those conclusions or concepts that cannot be “put to the test” or critically evaluated and potentially falsified are non-scientific in nature. Examples could include common-sense tautologies such as “It will rain” (which will most assuredly occur somewhere on Earth at some point in time) or beliefs related to theology or metaphysics. Popper also criticized pseudo-science, or that which masquerades as science, as “intellectually disreputable” (Ormerod, 2009, p. 445) and more akin to myth for its ability to tell a compelling story (Thornton, 2009). This category of non-science may have its roots in academic discourse but it is not actual science. Examples, for Popper, include Freudian psychoanalysis, Adlerian individual psychology, and Marxist sociopolitical theory (Popper, 1976, 1994). Popper felt that these examples of pseudo-science stand in stark contrast to what he saw as the scientific power of theories like Einstein’s theory of relativity. This was so for Popper not just because of the perceived intellectual heft of Einstein’s research but because, as Einstein himself declared, the theory was inherently risky in that it was highly exposed to the possibility of being falsified. Einstein’s theory was a “bold conjecture” (to use the Popperian term) that risked potential falsification through subsequent deduced instances of empirical non-confirmation or in-principle refutation. In the case of Freud’s and Adler’s psychological theories, Popper (1976, 1994) concluded that these theorists’ attempts to explain all forms of possible human behavior were imprecise and non-predictive to the extent that falsifying instances could not be empirically shown. Popper’s criticism of Marxism as a scientific sociopolitical theory

was not that it was lacking in specifics or predictive consequences like Freud's or Adler's theories, but rather that Marx's theory was continually saved from falsification by a series of *ad hoc* hypotheses added on to later reconcile the theory with actual events or facts. Taken to the logical extreme, a theory of this sort can devolve precipitously into dogma, thereby further removing it from any scientific considerations (Popper, 1976, 1994).

Non-scientific theories can be meaningful and potentially useful in developing pre-scientific hypotheses, Popper allowed. Yet, non-scientific theories suffer from their propensity for either fitting *a priori* all observations and consequently being non-falsifiable, or becoming a patchwork of *ad hoc* hypotheses designed to fit non-confirming data (Ormerod, 2009; Popper, 1959). For Popper, a theory is scientific only if it is open to falsification.

To summarize, "Science is not a system of certain, or well established, statements; nor is it a system which steadily advances towards a state of finality. Our science is not knowledge (*episteme*): it can never claim to have attained truth, or even substitute for it, such as probability... *We do not know: we can only guess* [original emphasis]. And our guesses are guided by the unscientific, the metaphysical (though biologically explicable) faith in laws, in regularities which we can uncover–discover" (Popper, 1959, p. 278). In substituting falsification for confirmation as the criterion of scientific discovery, Popper helped provide a compelling answer to the problems of induction and demarcation, thereby upending the centuries-old primacy of the inductive process as an originator and justifier of hypotheses.

If it is accepted, at least tentatively, that Popper's answers are correct and that he has resolved the fundamental problems in describing what constitutes epistemological

knowledge, a dilemma nevertheless arises. Left unresolved is the conundrum of what, in fact, to believe and how to move forward rationally in an unverifiable, uncertain world. With no universal, verifiable, or timeless truths available, and all that is known nothing more than a collection of hypotheses, theories, or conjectures, what then accounts for the accumulation of knowledge and, by extension, the survival of human life?

The accumulation of knowledge as the elimination of error.

Popper's explanation for how knowledge is acquired relies on, first of all, fundamentally re-envisioning knowledge not as movement towards a utopian state of true and complete knowing but instead as a process of error discovery and error elimination (Popper, 1934/1959, 1963, 1976, 1994, 1999). From this perspective, Popper's reconceptualization of knowledge accumulation (i.e. learning) can seem as disconcerting as it is counter-intuitive. Human survival depends on discovering, understanding, and expecting regularities in the world, regularities that can be anticipated and depended upon. Cold winters need to be followed by hot summers so that crops can grow, babies need to know that their cries will alert their care-givers to provide nutritional and emotional nourishment, and humans need to be able to expect that objects naturally fall in the direction towards the earth as opposed to floating up towards the sky. Whether as basic as knowing that the sun rises every morning or as experimentally sophisticated as discovering that metal expands when heated, acknowledging that life's observed regularities should be considered mere conjectures or hypotheses and not certain knowledge requires a significant degree of tolerance for ambiguity. It conflicts with human nature, especially in the modern age, to easily understand and accept that facts that are "scientifically proven" can never be completely verified and are continuously

open to being falsified. Popper was not unaware of this apparent conundrum, yet he believed that the considerable fragility of preserved human knowledge is as natural and timeless a part of life as the human expectation that the sun will come up tomorrow.

Although he did not devote much of his efforts to assuaging the affective uncertainties his critical fallibilistic epistemology might engender, Popper did attempt to show how the elimination of error serves to advance human learning. Popper (1976, 1999) considered life to be a constant process of problem solving, a process that could be succinctly described through the visual map he presented as: $P1 \rightarrow TT \rightarrow EE \rightarrow P2$. In this schema, P1 represents Problem 1, a first noticed or encountered problem. Problems are broadly envisioned by Popper to refer to those situational descriptions in which anticipations of a regularity in life do not match the reality encountered. These problems, according to Popper, are the starting point for the human learning or knowledge building process (Popper, 1999). Problems can be and are anything that one's engagement with the world brings about: they can be empirically as trivial as, "Why is the toaster not toasting the bread this morning?", as potentially life threatening as, "I see a hungry lion approaching! What should I do?", or as scientifically engaging as, "Why does water become a solid when the temperature drops below 32 degrees Fahrenheit?"

Following the recognition of a problem situation, the next stage in Popper's schema is the formation of a tentative theory (TT) that is proposed to solve the problem or resolve the discrepancy. Although described as a tentative theory in the schema, Popper also interchangeably used the terms conjecture, hypothesis, anticipation, or tentative solution when referring to the as-yet-not-determined or projected tentativeness of this stage (Bailey, 2000; Popper, 1976, 1999). Whichever terminology is used,

however, the central distinguishing feature of Popper's philosophy is the anticipatory, active nature of proposing a tentative theory and formulating a trial solution. It should be clear from this aspect of Popper's schema that Locke's canonical conceptualization of the human mind as *tabula rasa* is clearly refuted in Popper's epistemology. As Popper (1960) stated, "Knowledge cannot start from nothing...the advance of knowledge consists, mainly, in the modification of earlier knowledge" (p. 55).

As the schema progresses, the tentative theory is "put to the test" in the surrounding environment to determine whether it is successful. It may be that more than one tentative theory is tested and that varying degrees of perceived success are obtained. Yet, for Popper (1976, 1999), the primary focus at this point in the process is on discovering error and selecting out the theory, or theories, that lead to the least amount of error. Hence, the error elimination (EE) stage of the process. As might occur with one of the previously mentioned problem situation examples, the malfunctioning toaster could potentially be fixed by plugging it into an electrical outlet. This conjecture (TT), when tested against the environment, may show that the toaster functions correctly and the bread is properly toasted. The error to be eliminated in this problem situation is not thinking to check whether the toaster is correctly plugged in prior to turning it on. Likewise, in another example, the advancing, hungry lion may need to be dissuaded from attacking through a show of force. A tentative hypothesis (TT) may be to throw stones at the lion to hurt it so that the lion reconsiders attacking and instead directs its attention to easier prey. As is true of all conjectures, the conjecture may succeed, but it is equally possible that it will not succeed and will be refuted. For example, the lion's hunger and fortitude may be strong enough that it attacks anyway and the error of the stone-throwing

hypothesis will be eliminated, although in this case not in time to prevent a human fatality.

As error is discovered and actively eliminated, Popper's schema moves toward the next stage: A new problem situation designated as P2. This second problem situation, Popper (1976, 1999) asserted, is counter-intuitively new. It may be, and most likely is, recursive, having grown out of what was discovered in the process of attempting to solve P1 and incorporating elements of what was learned or not learned; however, the context and dynamics of this problem situation nonetheless require unique tentative theory and error elimination stages. As Popper described it, the new problem is a "...more sharply focused problem ..." (Popper, 1999, p.13) and "...new problems arise from our own creative activity; and these new problems are not in general created by us, they emerge autonomously from the field of new relationships which we cannot help bringing into existence with every action ..." (Popper, 1967, p. 71). To extend the example of the hungry lion problem situation just mentioned, a different tentative theory may be hypothesized by a fellow human who witnessed the tragic end of his or her friend and who consequently learned the inadequacy of using small stones against a hungry and powerful lion. The new hypothesis might instead involve utilizing a long wooden stick with a flaming end to it as a defense against the next hungry lion. When put to the test, this conjecture may prove sufficient (or not) to ward off the lion's advances.

Falsification and the verisimilitude of scientific theories.

A key point in Popper's problem situation schema that needs further elaboration is his rationale for determining which theories have best survived the error elimination process. Often, there are multiple numbers of theories that can be deductively tested with

more than one theory proving successful or partially so. For Popper, the competition among successful theories boils down to deciding which shows greater empirical content and, by extension, which has greater predictive power. The bolder the theory, or the more it asserts and predicts, the greater risk it runs of being falsified. Surviving subsequent tests that seek to falsify the theory demonstrates the theory's mettle and argues for its provisional acceptance as better approximating the truth. Popper termed this state of provisional acceptance *verisimilitude*. Popper (1934/1959, 1963) also repeatedly emphasized that, regardless of the degree of verisimilitude and the extent to which a theory can be corroborated, corroboration does not equal verification. There are no universal, verifiable truths: theories may point towards an imagined or hoped for utopian ideal of theoretical truth but they are inherently falsifiable (Popper, 1934/1959, 1963).

Popper frequently cited in his work the example of the overthrow of Newton's 17th century theory of gravitation by Einstein's 20th century theory of relativity as compelling support for his own theory of verisimilitude (Popper, 1999). Newton's theory had a high degree of empirical content and predictive power and had served as the benchmark mechanical explanation of gravitational force for centuries. However, in Popper's view, Einstein's theory served to subsume Newton's by first explaining all of what Newton had successfully explained and by then extending beyond Newton's principles the range of questions that Einstein believed his theory could answer, i.e. its predictive power. The verisimilitude of the theory of relativity was later deductively corroborated, was extensively critically discussed, and achieved acceptance within the scientific community. Hence, according to Popper (1999), the theory of relativity was shown to be a closer approximation to the truth.

Popper appears to be indebted to Einstein, or at least strongly influenced by him, in regards to Popper's belief in the importance of falsifiability. Einstein was quite clear in his theoretical description of gravitation as to the kind of empirical tests that might (and should) be employed to defeat his theory or to better show its incompleteness (Popper, 1999). This awareness of theoretical incompleteness, for Popper, was to be embraced and encouraged so that yet bolder and riskier theories may be posed (or deposed, as the case may be), all towards the goal of pushing knowledge forward through the reduction or elimination of error.

Popper attempted to formally define his conceptualization of verisimilitude both qualitatively and quantitatively (see Popper, 1963), in part to show how a given Theory A may be closer to the truth (i.e. further from error) than a given Theory B. This was achieved by dividing theoretical content into two classes—truth content and falsity content. Truth content refers to the theory's class of propositions considered true or correctly derived from what the theory asserts. Falsity content, on the other hand, is the class of propositions that lead to false conclusions or consequences (Thornton, 2009). This definition was intended to explicate how, through the elimination of theories that have been falsified in spite of being at least partially true, other theories with higher levels of verisimilitude may be accepted. The part of Popper's formal definition of verisimilitude that describes a theory's truth content has generally been accepted; however, as Ladyman (2002) and Thornton (2009) pointed out, the part of Popper's formal definition that describes a theory's falsity content has been shown to be incorrect. Popper subsequently acknowledged his mistake but asserted that his central tenet of the concept of verisimilitude still stands, primarily because of its heuristic value.

Criticisms of Popper's Epistemology

Popper's theories, as he would surely agree, are not immune to critical discussion, and the scope and tenor of the debate over his epistemological views varied throughout his long career. Initially, around the time of Popper's publication of *Logik der Forschung*, many of the Logical Positivists within the Vienna Circle considered Popper a kindred spirit whose views complemented or were easily reconciled with their own. It was thought by some, for example, that in establishing a criterion for meaningfulness, Popper might be convinced that his principle of falsifiability would be better formulated as verifiability (Popper, 1976). This comity would not last, though, as a fuller understanding of the consequences of Popper's anti-inductivist and anti-dogmatist position were realized. Although Popper was perceived (incorrectly) by many philosophers in Britain and the United States as a Logical Positivist, perhaps because some of his earliest work was published as part of a series edited by the Positivists Frank and Schlick, Popper sought from the beginning to correct the many errors promulgated by those most closely associated with the Vienna Circle (Popper, 1976).

The eventual falling out between Popper and the Logical Positivists (although there never had really been any serious affinity from the beginning) is perhaps best characterized by a public row that occurred between Popper and Ludwig Wittgenstein during a lecture that Popper gave at a 1946 meeting of the Moral Sciences Club in Cambridge, England. As Popper (1976) described it, Popper was attempting to respond to Wittgenstein's proclamation that philosophy contains no genuine problems, only linguistic puzzles. A heated exchange between the two, in part precipitated by Wittgenstein's alleged manhandling of a nearby fireplace poker, resulted in Wittgenstein

storming out of the lecture. The “fireplace poker incident,” as it came to be popularly known (see Edmonds & Eidinow, 2001), is a fitting metaphor in the authors’ view for the severe poking that Popper gave to Logical Positivism’s smoldering ashes with his emphasis on a hypothetico-deductivist, critical fallibilistic approach to the growth of human knowledge.

A more specific criticism of Popper’s epistemology relates to the question of how basic or existential statements can falsify scientific non-existential laws or universal statements if basic statements are themselves not derivable from scientific laws. Popper had asserted that scientific laws work in conjunction with statements that describe initial conditions to yield implications that, if false, can falsify the original law. However, Putnam (1974) pointed out that specific singular basic statements are not the only kinds of statements that can be used to bind a universal law or theory and a prediction. There is also the possibility of other general statements, which he termed auxiliary hypotheses, being involved. In cases in which a given prediction is shown to be false, it is therefore unknown whether this is so because the scientific law or one of the auxiliary hypotheses has been shown to be false. Because scientists are more likely to assign responsibility for a resulting false consequence to auxiliary hypotheses than the universal law, Putnam argued that scientific laws are for this very reason unlikely to be declared as false.

In reaction to this stream of criticism, Putnam (1974) and Thornton (2009) asserted that Popper was forced to make a significant shift in his position to one that acknowledged the impossibility of demarcating science from non-science solely on the basis of falsification of scientific statements. Instead, auxiliary hypotheses do need to be taken into account in ways that serve to differentiate instances of the scientific

modification of universal laws or statements from *ad hoc* attempts to do so. This change in Popper's position, the authors contended, has weakened Popper's grounds for asserting falsificationism as the preferred approach to the verificationism pursued by most inductivists.

A somewhat related criticism of Popper that also involves basic statements and falsification is Thornton's (2009) assertion that Popper seemed guilty of arbitrarily determining whether a given basic statement is a potential falsifier of a hypothesis or should instead be considered an actual falsifier. Popper considered all basic statements fallible and "theory-laden" because all sense data observations must be actively interpreted through the theoretical framework of an observer. Consequently, Popper believed all basic statements to be open-ended hypotheses that can be neither verified nor confirmed through experience. Thornton concluded that Popper was guilty of a sophisticated variety of conventionalism for not acknowledging the inconsistency of believing a theory falsified through a process that allowed basic statements to be accepted as a free decision, as Popper claimed in *Logik der Forschung*. Thornton (2009) found Popper's version of conventionalism incompatible with classical conceptions of science moving closer to the truth.

Lakatos (1974) criticized Popper's theory of demarcation from the perspective of questioning Popper's assertion that critical tests can, and should, be employed to separate scientific hypotheses from non-scientific hypotheses. Popper often referred to Galle's discovery of the planet Neptune, which was based on Adams' and Leverrier's predictions using Newtonian physics, as a prime example of a way in which a theory can be put to a rigorous test. However, Lakatos rejected Popper's conceptualization of critical tests in

science by suggesting that if Galle, to continue the example, would not have found Neptune, Newtonian physics would not likely have been repudiated. Lakatos' point was that non-corroboration does not necessarily equal falsification and that so-called strong scientific theories are rarely, if ever, considered falsified from only one set of observations. It was Lakatos' contention that falsification requires gaps in research much larger than what a Popperian critical test might indicate, stating that, "In general, Popper stubbornly overestimates the immediate striking force of purely negative criticisms" (Lakatos, 1974, p. 248). For Lakatos, a theory should be rejected only if a better theory i.e. one which has "excess empirical content" (p. 250) is available to replace it. Research programs serve as better "units of appraisal" than theories do, and it should be the "positive heuristic" (p. 248) of the program, and not the associated anomalies, that define the choice of problems to be investigated (Lakatos, 1974).

Berkson and Wettersten (1984) criticized Popper for the dichotomy that Popper claimed existed between a philosophy of learning and a psychology of learning. Popper asserted that basing a philosophy of science on psychology, and likewise basing a philosophy of psychology on science, would beg the question, hence the necessity of keeping the two clearly distinct. Berkson and Wettersten agreed with Popper's rejection of the certainty of knowledge, whether that certainty derived from either a Humean or Kantian perspective, and with Popper's belief in the elimination of error as a necessary focus in acquiring knowledge. However, the authors asserted that Popper's psychological learning theory was sublimated to that of his philosophical theories, especially the nature of scientific knowledge building –all to the detriment of understanding his unique brand of the psychology and methodology of discovery. The authors emphatically saw a very

close relationship between the two and faulted Popper for “...producing too rigid a model of the influence of reason on the choice of scientists” (p. 149). Bailey (2000) concluded that Popper’s epistemology moved closer to methodology as his career progressed but that Popper never explicitly explored this evolving relationship. Bailey’s perspective seems congruent with Berkson and Wettersten’s argument that Popper failed to demonstrate the lack of relevance of the psychology of discovery to the logic of discovery. This accusation was explicitly expressed through Berkson and Wettersten’s statement that promoting “...a recommendation as to method on an understanding of the nature of mind is not to commit the error of psychologism, and such reliance does not confuse issues of logic with those of empirical science for the logic of discovery is not pure logic, but practical methodology” (Berkson & Wettersten, 1984, p. 33).

Popper’s Critical Fallibilism as an Evolutionary Epistemology and Blind-Variation-and-Selective-Retention (BVSR) Process

If Popper’s notion of verisimilitude were to be accepted, at least in its weaker version as a useful heuristic, then the process of error elimination and the decisions made regarding the worthiness or warrant for accepting the better of a set of competing theories begins to resemble a selection process of the fittest, most-likely-to-survive theories. Just such a characterization of Popper’s philosophy was proposed by Campbell (1974) to highlight the Darwinian nature of hypothesis testing against the environment to which theories, in Popper’s view, should be subjected. Campbell’s comparison of Popper’s epistemology to Darwin’s theory of evolution provided support for Campbell’s description of Popper’s epistemology as an *evolutionary epistemology*, and Popper himself identified “...as the founder and leading advocate of a natural-selection

epistemology” (Campbell, 1974, p. 450). In this view, the learning process moves forward to solve problems in a blind, although anticipatory manner. Organisms cannot know *a priori* whether a proposed conjecture or group of conjectures will succeed, hence a blind variation upon the previous existing knowledge set. As Campbell (1974) stated, “In going beyond what is already known, one cannot but go blindly. If one can go wisely, this indicates already achieved wisdom of some general sort” (p. 422). Upon weighing the result(s) of the tests against the environment, those theories or elements of theories in error are distinguished from those which succeed (wholly or partially). A decision is then made and the successful theories or elements of theories are “selected out” and retained for future utilization, resulting in what Campbell comprehensively described as a blind-variation-and-selective-retention (BVSR) process (Campbell, 1960, 1974, 1997).

The BVSR process, for Campbell, was a fundamental knowledge building process that depends on three necessary conditions: “...a mechanism for introducing variation, a consistent selection process, and a mechanism for providing and reproducing the selected variables” (Campbell, 1997, p. 8). Campbell further asserted that the BVSR process may invoke shortcuts that appear to accelerate knowledge acquisition; however, these shortcuts are described as the result of previous full-fledged BVSR processes and may substitute “...for overt locomotor exploration or the life-and-death winnowing of organic evolution” (Campbell, 1997, p.8). An inference drawn from this final point may serve as an account of the importance of human language as an evolutionary advantage resulting from the BVSR process. As such, it is just one example of how Campbell’s extension of Popper’s evolutionary epistemology can highlight the ways in which a Darwinian learning process might account for “...the emergence of more behaviorally flexible

organisms” (Bailey, 2000, p. 67). Behavioral flexibility, in turn, confers an evolutionary advantage to successful theories, whether directly related to immediate survival of a living organism or, at the other end of the spectrum, to the critical discussion of scientific theories in pursuit of the advancement of scientific knowledge. Although Popper did not originally conceive his philosophy with as explicit a link and biological analogy to Darwinism as what Campbell later deduced, Popper acknowledged the fruitfulness of the comparison (Popper, 1973, 1977, 1994, 1999).

Applications of Popper’s Evolutionary Epistemology to Educational Theory

As influential as Popper’s ideas have been in modern philosophy, the philosophy of science, and sociopolitical theory, there has been comparatively little literature devoted to potential applications of Popper’s epistemological views in educational settings. However, the Darwinian, BVSR aspect of Popper’s critical fallibilism has proven useful to three educational theorists, in particular, who have sought connections and applications of Popper’s propositions to specific learning environments. The work of these theorists – Perkinson, Bailey, and Swann– centers around a common theme drawn from Popper, namely that students should be conceived as active, purposeful agents in the learning process who create knowledge through a process of trial-and-error elimination.

Perkinson and the three metaphors of western education.

Perkinson (1984) described three metaphors that trace the development of the philosophical basis of western education dating from the ancient Greeks. The first metaphor is the idea of education as initiation. Initiation, for the Greeks, was more than just the social rite of becoming a “member of the club”–it involved studying the content of the great works that the club’s members considered emblematic of Western

civilization's cultural heritage. Teachers served as facilitators of the students' initiation into the fraternity of learned men and western culture as a whole; however, the content of the culture took center stage. This conceptualization of education as initiation was both highly influential and long lasting. The great works, studied in Greek, or later, Latin, served as an almost utopian model of what education should revolve around, and the model did not begin to lose much significance until the Scientific Revolution gained steam in the 17th century.

Traditional wisdom gradually came to be seen as less important than unearthing new knowledge of the way the real world works through careful scientific observation, leading to Perkinson's second metaphor of education as transmission. In this view of education, teachers served as the arbiters of what, how, and when subject matter should be taught, and students focused on learning the facts that are duly transmitted from teacher to student. The process of transmission elevated the position of teacher to the center of instruction and gave teachers not only the responsibility but also the power and authority to motivate (positively or negatively) and shape students' learning behaviors (Perkinson, 1984).

It should be observed that the first two of Perkinson's metaphors of education, initiation and transmission, describe human learning from the vantage point that learning is something that happens *to* students. Learners are viewed as passive receptacles waiting, as it were, to be written upon as if Lockean blank slates, impressed upon as a signet ring presses into soft wax, or filled up like the Popperian empty bucket. Regardless of the analogy used, these two metaphors construe knowledge as something that originates from without, not from within. Further, in formal educational settings, knowledge comes from

a more capable and wise cultural tradition or teacher. Although there have been some instances over the centuries of philosophers or teachers who have questioned to varying degrees these conceptualizations of human learning, Perkinson (1984) attributed the beginnings of a slow but inexorable rebellion against both prevailing metaphors to the work of Rousseau. It is in Rousseau's call to reject the authoritarianism of the unequal and constraining dynamics of the transmissionist style of education that Perkinson saw the beginnings of the development of the third and most current metaphor: education as growth.

The metaphor of growth shifts the dynamics of the teacher-student relationship to a student-centered model in which students are active creators and directors of their knowledge building process. Knowledge building, in this view, best occurs in learning environments that are Popperian in nature: errors or contradictions between present knowledge and the environment are noted, new hypotheses are generated and tested –all within an educational setting that positions teachers as enablers and supporters of this trial-and-error elimination process. Perkinson (1984) acknowledged that many vestiges of both previous approaches to education remain in even some of the most current practices, but he cited, in particular, the work of Montessori, Piaget, and Rogers as exemplifying some of the better education-as-growth models that could be described in terms of the evolutionary epistemology that Popper's work supports.

Bailey and the importance of seeking error in educational environments.

Bailey (2000), who also traced his theoretical roots to Popper, cautioned that, contrary to what has become an assumption for many student-centered educators, “Children do not simply pick up information or associations from the environment...but

require an environment that can challenge their prejudices and expectations” (p. 203).

The author further asserted that challenging students’ expectations is most fruitful within a supportive learning environment that encourages trial explorations and does not penalize any resulting errors. Although not explicitly stated, Bailey’s stance of not penalizing errors serves to directly contradict both traditional learning theories and the majority of current assessment practices upon which formal education is based. Within the traditional educational context, avoiding error is paramount to achieving good grades in school, to producing what teachers expect in student behaviors, and to protecting students’ sense of self-confidence and peer acceptance. However, Popper’s evolutionary epistemology requires an active exploration of the environment for the BVSr process to be fully exploited and those explorations typically seek out and embrace the discovery of error. As Bailey (2000) described, there is a clear role and responsibility in educational settings for teachers to facilitate these explorations. According to the author, this should be accomplished by shaping the structure and processes of the learning environment so that students’ explorations are fostered and supported, as well as critically evaluated when errors are discovered.

Swann and Popperian-derived pedagogy and learning environments.

Swann (2006, 2007a, 2007b, 2009) has extensively argued for the incorporation of an applied Popperian approach to school curricula and teaching pedagogy. The author agreed with Popper’s contention that learning is a type of problem solving and that conjectures or trials in solving problems move forward blindly in a process of error discovery and elimination. Swann (2006) considered her approach to education within a BVSr Popperian-inspired framework as more structured than Perkinson’s (1984) and has

placed comparatively less emphasis on the value of tradition that Bailey (2000) has subsequently emphasized. However, Swann clearly summarized her agreement with her fellow educational theorists by stating that “Popperian selectivism offers a theory of what happens when learning takes place –that is, of the nature of the process of learning, rather than merely of how learners learn” (Swann, 2007a, p. 49). Swann (2007a) further asserted that “...philosophical errors often lead to, or compound, errors in psychological theorising [*sic*]” and that it is incumbent upon all educators to study and learn from philosophy because “...philosophical assumptions are embedded in the politics and practices of education, teaching and learning” (p. 39). This author described her Popperian-based epistemology of learning as one that is an inherently creative and mostly unconscious BVSr process that unfolds within learners, rather than one that is forcibly transmitted from without to (or onto) learners (Swann, 2006, 2007a, 2009).

A noteworthy aspect of Swann’s work that goes beyond her bold prescription for the development of more Popperian-derived learning environments is Swann’s pleas for changes in the ways schools devise curricula so that efforts can be made to support student-initiated curricula. Based on Popper’s assertion that, when designing effective approaches to formal education, it is best to “avoid giving unwanted answers to unasked questions,” Swann (2006) developed a multi-stage procedure for organizing curricula that support Popper’s vision for education. The primary focus of Swann’s recommendation for student-initiated curricula is to address students’ needs around the problems that the students themselves identify. Teachers, in this view, have the responsibility for facilitating student problem discovery, helping students plan their learning (as

appropriate to the specific learning environment and institution), and engaging students in a form of dialog to promote the EE and P2 stages of Popper's learning schema.

Further, Swann (2007b) asserted that student-initiated curricula are integral not only to facilitating "good" learning in a Popperian context but also to promoting full learner autonomy—a concept often recognized in educational circles as important but that just as frequently is not evidenced in the pedagogical practices of many teachers. Swann believed that there is a close correlation between the perils of denying students the opportunity to increase their performative abilities through taking on responsibility for curriculum content and the concomitant limited development of learner autonomy. This pejorative constraint can also be perceived by learners as connected with other negative affective perceptions such as coercion or social and personal manipulation. To address some of these concerns more directly, Swann (2006) specified a set of maxims related to the conduct of teaching that could serve as guidelines for teacher training. These guidelines, according to the author, would enable teachers to develop an applied pedagogy that is consistent with Popper's core epistemological beliefs and is adapted to the realities of institutional learning environments.

The Montessori System of Early Childhood Education as Potential Exemplar of a Popperian Evolutionary Epistemology

Although there is no reference in Swann (2006) to other theorists or practitioners that have shared similar applied perspectives, it is interesting to note that many of Swann's recommendations appear to echo and validate many of the practices integrated into Maria Montessori's system of early childhood education from nearly a century before. The Montessori system, as previously mentioned, will be explored in greater

detail in Chapter 3; however, a few examples that coincide with some of Swann's recommendations provide a useful preview. Swann's fourth thesis focuses on the discovery of error as the "...principal means by which learning can be accelerated" and her first thesis asserts that "there is no learning without autonomous activity on the part of the learner" (p. 263). Both of these theses could be considered from the Montessorian perspective of the auto-correcting didactic apparatus that students interact with in the Montessori prepared environment. The prepared Montessori environment does not constrain students' initiative through imposed limits on the amount of time students can engage in their work. Nor does Montessori allow teacher correction of students' mistakes unless students have not yet fully understood how to properly use the apparatus with which they are attempting to work. Likewise, Swann's 12th thesis that advocates for teachers to organize curriculum on the basis of students' learning problems suggests implicit support for Montessori's system of hierarchically arranged tasks that are designed to engage students in explorations and learning within their student-initiated curriculum. The different types of *work*, as student tasks and the didactic apparatus are called in Montessori classrooms, are sequentially arranged according to increasingly complex cognitive and performative parameters. Teachers guide students to select new, more challenging work from the array of didactic apparatus based on the teachers' close attention to students' indication of readiness. This process, while unpredictable from the standpoint of the timing of individual student readiness, is nonetheless highly organized and emanates completely from the students.

If Swann's proposals are correct, as well as those perspectives of her like-minded educational theorist colleagues, then the process of building better curricula around

Popperian-based learning environments, and refocusing teacher preparation and teacher roles within those environments, would also likely benefit from more closely examining the principles and practices of the Montessori system of education. Although human learning is not restricted to any one approach or technique, Popper's evolutionary epistemology may be an important factor in understanding the ways and extent to which the Montessori system has come to be perceived as highly successful in facilitating naturalistic learning in children –learning that occurs across varied cultural and linguistic backgrounds and at ages significantly younger than had ever been previously considered (A. Lillard, 2007). Popper's description of knowledge accumulation as the discovery and elimination of error through repeated problem solving and testing of theories or hypotheses seems to be at the core of how students interact with the didactic apparatus in the prepared environment of the Montessori classroom.

It is this bilateral relationship between Popper's explanations of the ways that knowledge is created and accumulated and Montessori's descriptions and applied principles of effective early childhood learning in a formal institutional environment that will be explored in Chapter 3. From this understanding, a model can then be suggested for an improved educational system that complements naturalistic human learning. This model, to be presented in Chapter 4, seeks to exploit to the fullest, practical extent the best practices of pedagogy, teacher preparation, and assessment of human learning in ways that are as intrinsically rewarding as they are productive and beneficial for learners and society alike.

Chapter 3: The Montessori System as an Evolutionary Epistemology

As previously discussed, there has tended to be broad, general agreement in the United States that getting a good education is foundational for Americans to build successful careers and for America to maintain a stable democracy with a healthy national economy. However, considerable debate has persisted throughout America's history regarding what actually constitutes a "good education." Influential developments affecting the historical trajectory of America's educational system were described, and it was acknowledged that, however influential any of these movements may have been, no one approach to schooling has ever completely supplanted or eliminated any other approach (Kliebard, 1995; Perkinson, 1968; Tyack & Cuban, 1995).

This dissertation has suggested that a more effective approach to answering current questions regarding the readiness of America's youth for tackling 21st century challenges would be to begin with a comprehensive analysis of what constitutes "real," "true," or "naturalistic" learning in human beings. Towards this end, Karl Popper's philosophy of knowledge acquisition, commonly titled as an evolutionary epistemology, was discussed as a theoretical framework from which to build educational practices that complement naturalistic human learning processes. Further described by Campbell (1974) as a Darwinian process of blind-variation-selective-retention (BVSR), Popper's evolutionary epistemology may serve as an explanatory tool for certain types of promising educational practices. Specifically, it was hypothesized that the Montessori system of early childhood education, an existing educational approach commonly perceived as successful with young learners across differing cultures, languages, and socioeconomic backgrounds, appears to evoke elements of Popper's trial-and-error

BVSR learning. A combined Popperian-Montessorian perspective, it was claimed, could therefore prove highly informative in future discussions aimed toward educational reform that complements naturalistic learning processes.

This third chapter begins by relating highlights of the unique path of Maria Montessori's career from that of a pioneering female medical doctor in Italy to educator of young children and head of an international educational movement. This section is followed by an extensive description and explanation of the primary principles, practices, and components of Montessori as viewed from three overlapping perspectives. These three perspectives –the Montessori conception of child, the role and responsibilities of the Montessori teacher, and the prepared environment– interact on multiple levels with the Montessori curriculum to create the unique, highly integrated system of education for which Montessori is famous. The chapter then concludes with a discussion of Montessori that looks at the extent to which the Montessori learning environment could be analyzed from the philosophical perspective of Karl Popper's evolutionary epistemology.

It should first be pointed out, though, that the attempt to describe Montessori's distinguishing features and to explicate their significance in early childhood education is complicated to a certain extent by the significant degree of integration of the components of Montessori's prepared environment (the didactic apparatus, the students, and the teachers) and also by the complex sequence and scaffolding of the learning tasks. Discussing the parts of Montessori necessarily involves simultaneously examining the whole. This can, at times, seem both confusing and redundant for the non-Montessorian. However, with the acknowledgement of the potential limitations that a semi-decontextualized description and analysis of Montessori might entail, the four

perspectives mentioned above will help to emphasize the most salient aspects of Montessori. It will be further argued that these themes serve to highlight the areas in which Montessori may most brightly reflect an applied evolutionary epistemology.

Throughout the ensuing discussion, Whitescarver and Cossentino's (2008) conventions will be followed for ease in differentiating between Maria Montessori (1870-1952) the person and Montessori the educational system that she created. Montessori the educational system will be referred to as simply "Montessori." Maria Montessori, the movement's founder, will be referred to as "Dr. Montessori."

The Nascent Montessori

Contrary to what has been reported by Dr. Montessori's biographers (Kramer, 1988; Standing, 1957), as well as most other authors in the literature, Dr. Montessori was not the first female medical doctor in Italy –she was preceded by at least five other women (Babini, 2000; Foschi, 2008; Povell, 2010). Nonetheless, at a time when Italian women from families with financial means rarely worked outside the home except as schoolteachers, Dr. Montessori's accomplishment in 1896 of graduating with a degree in medicine was rare indeed. This achievement was made even more distinctive by her decision to specialize in psychiatry, a choice considered more "masculine" than pediatrics or gynecology would have been perceived at the time (Babini, 2000).

As part of her responsibilities as a doctor and researcher in the psychiatric clinic at the University of Rome in the late 1890s, Dr. Montessori visited Rome's asylums to select potential patients for treatment in the university's clinic. It was through this first-hand contact with the children who were confined to living in the deplorable conditions of Rome's asylums that Dr. Montessori's professional interest in education and childhood

learning has its beginnings (Kramer, 1988). By today's standards, the children who Dr. Montessori encountered in the asylums of her era would most likely be considered special needs children with varying degrees of autism or Down's syndrome, and they would receive an education appropriate to their developmental abilities. However, as was the custom of the times, these "mental deficient," "imbeciles," "idiots," or "feeble minded" people, as they were called, were warehoused with and mostly left to fend for themselves among the severely mentally ill in conditions that were as filthy as they were inhumane (Kramer, 1988; Montessori, 1912). What especially intrigued Dr. Montessori was the behavior of the special needs inmates at feeding time. Food rations were meager and typically "thrown to the wolves" for the inmates to fight over. Dr. Montessori was surprised to observe that, as hungry as the special needs inmates were, they played with the food, carefully examining its appearance, smell, and texture, apparently more starved for the novel sensory stimulation the food provided than for the sustenance of the food itself (Kramer, 1988; Montessori, 1912).

Dr. Montessori began to work more intensively with this population of developmentally challenged individuals in 1897, applying the techniques of two French doctors, Jean-Marc-Gaspard Itard and Edward Seguin, who were pioneers in the nascent field of special education (Montessori, 1912). Itard had become well known for his work with the so-called "wild boy of Aveyron." This boy, who was discovered around age 12, had spent nearly all of his formative years living among animals in the wild, devoid of any human contact or interaction. Itard (1932) chronicled his unique efforts to educate the boy, teach him a human language, and acculturate him as best as possible to contemporary French society. Although Itard's efforts were only moderately successful,

he established an approach to special needs education that was influential, flexible, and innovative. Seguin, a student of Itard's, further developed Itard's techniques and physiological principles, applying them in his work with special needs students in France and, later in his career, in the United States (Seguin, 1866). Dr. Montessori (1912) acknowledged that she was especially influenced by the efficacy of Seguin's three-period teaching methodology and sensorimotor learning materials, and she successfully adapted Seguin's method and materials for use in her work with cognitively challenged children in Rome's asylums. Importantly, Dr. Montessori came to believe that the challenge for her and her patients was primarily pedagogical in nature and not medical. Further, just as Seguin had begun to demonstrate some 50 years prior, special needs children were fully capable of learning but through methods that were not the standard educational methods (Kramer, 1988; Montessori, 1912; Plekhanov, 1989).

Dr. Montessori's efforts with this population of students were so successful that some of the students made enough progress to sit for the qualifying exam to enter Rome's public schools. Remarkably, these "mental deficient" scored equal to or better than did the non-special needs children taking the same exam (Kramer, 1988; Plekhanov, 1989). Although certainly pleased with the numerous plaudits she received for the extraordinary performance of her students, Dr. Montessori was more circumspect than celebratory, puzzled by why Italian children of normal intelligence scored so poorly relative to the performance of supposedly less capable special needs children (Kramer, 1988). Intrigued by this dichotomy in performance between the two groups of children, Dr. Montessori's research focus shifted, as Babini (2000) reported, from psychiatry towards anthropological research related to women and children, in particular the relationship

between intelligence and social conditions and that of intelligence and skull size (anthropometry). Dr. Montessori was eventually certified as a university lecturer in anthropology in 1904 and became well known within elite Roman circles as an expert in pedagogy (Babini, 2000; Foschi, 2008).

According to Foschi (2008), Dr. Montessori's accomplishments led Eduardo Talamo, the general manager of the Roman Institute of Real Estate (IRBS), to ask her to direct a new school for economically disadvantaged children of normal intelligence that was to be housed in a new apartment building in the San Lorenzo "slum" district of Rome. Talamo's goal was to provide clean, bright housing with amenities like gardens and toilets, as well as an on-site pre-school for young children whose mothers needed to work during the day. As progressive minded as Talamo might have seemed for the era, the motives of IRBS' owners, however, were not entirely altruistic. Foschi (1988) and Kramer (1988) both reported that it was hoped that by providing children between the ages of three and seven with a school-like setting to occupy their time while their parents were away, the children would be less likely to deface and ride roughshod over the new apartment buildings. Foschi (1988) further described Talamo's efforts to provide the economic incentive of reduced rent for exemplary families who enrolled their children in the *Casa dei Bambini*, or Children's House pre-school, and who took good care of their apartments. The intended benefit to IRBS, of course, was improved profitability and a fatter bottom line. Dr. Montessori, on the other hand, saw in this arrangement a unique opportunity to forge a new pathway in society that aimed at transforming not only children's education at one level but also emancipating women and alleviating extreme poverty on another level (Babini, 2000). As quoted in Babini (2000) from a speech given

in Italian by Dr. Montessori, the doctor believed that her scientific pedagogy promised to “...become the new social medicine” (p.64).

Despite these lofty sentiments, the *Casa dei Bambini* had a very humble beginning when it opened on January 6, 1907. Nothing was provided except a large room and the barest of materials. Assisted only by the daughter of the building’s porter, Dr. Montessori designed and cobbled together what were to eventually become signature trademarks of the Montessori system: child-sized tables, low storage cabinets, and small chairs. She also continuously closely observed her new students and their use of the customized didactic materials that she was constantly refining. Dr. Montessori (1912) described this period of experimentation by stating that, “Here lies the significance of my pedagogical experiment in the ‘Children’s Houses.’ It represents the results of a series of trials made by me, in the education of young children, with methods already used with deficient” (p. 45). She further described the results of her research by stating that, “Much of the material used for deficient is abandoned in the education of the normal child –and much that is used has been greatly modified” (p. 169).

It is noteworthy that, even at this very early stage of development, the Montessori methodology evidenced an evolutionary epistemology at a variety of levels of analysis. Dr. Montessori’s creation of an educational system that radically departed from commonly accepted practices was not only a Popperian-like bold assertion but also an example of a bona-fide trial-and-error process. Chattin-McNichols (1992) claimed that Dr. Montessori was an “eclectic borrower” who modified many of the materials and methods, particularly Seguin’s, that she had used with special needs children for use with children of normal intelligence. Additionally, Dr. Montessori’s educational laboratory of

the *Casa dei Bambini* required that new teaching practices and materials be invented and piloted. Throughout this period, and for decades to follow, Dr. Montessori engaged with a BVSR process as she gradually determined through her clinical trials and observations what seemed to work and what did not. This enabled her to make decisions as to what should be eliminated or retained in the evolving Montessori system, an applied research approach that she continued to pursue throughout her long professional career.

As Foschi (2008) asserted, the Talamo-Montessori experiment was highly successful and served to quickly establish Dr. Montessori's method. Standing (1957) and Kramer (1988) reported that a long list of Italian and international dignitaries trekked to the *Casa dei Bambini* to see firsthand the unbelievable transformation of these lower class children widely thought to be as uneducable as they were incorrigible. Despite Dr. Montessori's eventual falling out with Talamo and the end of their collaboration two years later, possibly fueled by what Foschi (2008) implied was Dr. Montessori's prodigious independence and initiative, the Montessori movement had begun.

This period of time was transformational for Dr. Montessori: she gradually gave up a promising medical practice to devote her entire career to perfecting and expanding her system of early childhood education. As Dr. Montessori's fame grew and word of the successes of the Montessori educational approach spread further, Dr. Montessori began to promote her Montessori system beyond Italy's borders by establishing Montessori schools, giving lectures, and training teachers first throughout much of Europe and then in countries in Asia and other regions of the world. With more than 22,000 Montessori schools currently in operation in over 110 countries, Dr. Montessori's system of childhood education has clearly endured and prospered worldwide (Whitescarver &

Cossentino, 2008). Unlike many educational innovations or fads that quickly fade in popularity, often to never return, the longevity of Montessori speaks to its perceived success in educating children from all walks of life. The influence of Montessori on children's education as a whole, although not often explicitly acknowledged, has been absorbed into even the most traditional learning environments –examples that Whitescarver and Cossentino (2008) described as “mixed-age grouping, individualized instruction, manipulative materials, and child-sized furnishings” (p. 2573). Here in the United States, the popularity of Montessori has dipped from its initial peak between 1911-1918 when it was first introduced. However, resurgent interest among parents and educators in the 1950s and again in the 1990s has served to sustain Montessori in the United States as a viable educational alternative to more traditional modes of schooling (Whitescarver & Cossentino, 2008). Notwithstanding Shute's (2002) uncharitable claim that Montessori in the United States “...is now more commonly applied to the oft-pampered offspring of the well-heeled” (para. 3), there continues to be a dedicated group of adherents and professional organizations in the United States that enthusiastically promote the potential benefits of a Montessori education for all.

A View of Montessori From Three Overlapping Perspectives

For parents and educators who have seen or experienced firsthand the educative power of Montessori, the rallying cry of “It works!” can often be heard. Plentiful examples, anecdotes, and an increasing body of empirical confirmation are regularly cited. What is less frequently cited, though, is *why* Montessori seems to work so well for so many. Indeed, it is this theoretical question that this dissertation seeks to begin answering. However, formulating an effective theory that attempts to propose a possible

answer to the question first requires that a more complete description of the unique principles and practices of Montessori be presented and explicated. The next sections of this chapter will describe some of the fundamental practices of Montessori from three overlapping perspectives: the Montessori conception of child, the role and responsibilities of the Montessori teacher, and the prepared environment. These three perspectives will then provide the necessary basis for the ensuing extended summary and analysis of the defining characteristics of the Montessori curriculum as well as detailed descriptions of representative examples of the curriculum's didactic apparatus.

Conception of child.

Dr. Montessori's conceptualization of children was likely shaped to a large extent by her experience and training both as a medical doctor and as a teacher. As a medical doctor, she spoke and wrote authoritatively on topics related to children's physiological health, for example the importance of proper hygiene, the necessity of fresh air and physical activity, and specific dietary guidelines that should be heeded for children's optimal growth and physical maturation (Montessori, 1912). Dr. Montessori's perspective as a medical doctor also seems to have informed more generally her developmental view of children as complex, younger human beings who proceed through a series of cognitive and affective stages concomitant with their physical maturation. This biologically oriented view of children growing in developmental sequences is commonly acknowledged today; however, Dr. Montessori's insights into the developmental nature of early childhood cognition perceptively foreshadowed the subsequent empirical research by Piaget that asserted very similar developmental stages and sequences (Chattin-McNichols, 1992; Saettler, 1990).

Dr. Montessori's perspective as a teacher also seems to have greatly influenced her conceptualization of children. She recognized and intensely respected children's innate, insatiable proclivity for learning about the world around them. This respect for children's ability to learn manifested itself in some fundamental ways as Dr. Montessori developed her educational system. For one, Dr. Montessori strongly believed that children younger than six years old were intellectually and developmentally ready for more complex tasks than what were commonly believed possible at the time (Montessori, 1912). Through her life-long crusade to change the prevailing attitude that children under six were not ready to learn, Dr. Montessori became one of the first true advocates for the benefits of early childhood education (Kramer, 1988; Standing, 1957). Montessori begins, for example, as a mixed-age classroom for children of ages 3-6 in which the didactic materials are sequentially arranged in terms of difficulty from simple-to-complete to difficult-to-complete in order to mirror the developmental capacities of children of this age group. Dr. Montessori (1912, 1914) indicated that one benefit of mixed-age grouping is that it allows the older, more proficient students to serve as peer role models for the younger, less experienced students. Furthermore, the extensive sequence of graduated, more complex learning materials and tasks helps scaffold the degree and direction of the students' learning.

Dr. Montessori's respect for children as individuals from whom teachers can learn informed every aspect of her approach to guiding children through their learning processes. Dr. Montessori (1912) asserted that children know when they are ready for the next new step of their learning. Although young children may be developmentally constrained in how they express this knowing, Montessori teachers are trained to

recognize certain signals that indicate readiness for the presentation to the child of the next, more complex level of work. These signals may be very subtle but the signals are evident and generally revolve around the ease with which a child engages the particular learning task and the student's apparent interest in continuing the work.

Unlike most traditional learning environments in which teachers control what, when, and for how long students are given to work on particular tasks, Montessori students are given the freedom to choose which task to work on as well as when to begin and the duration of the activity. Provided that the teacher has presented the correct way to "do the work" (i.e. modeled use of the didactic materials) and the student is developmentally ready to demonstrate his or her understanding of and ability to accomplish the specific task, students themselves determine their level of engagement with the curricular tasks. As P. Lillard (1980) stated, "In establishing freedom in the classroom, it is important to remember that freedom is based on choice, and choice is dependent on knowledge. The child must be prepared with knowledge of his environment, how to function there, and what use he can make of the materials there" (p. 225). Furthermore, students generally work independently with little further intervention by the teacher unless the work is being used improperly or the student's opportunity to work is being interrupted by other students in the class (A. Lillard, 2007; Montessori, 1912).

The significant degree of freedom Montessori students have in determining for themselves what, when, and for how long they engage with a particular task is integrally linked to Dr. Montessori's conceptualizations of "child" and "liberty." Dr. Montessori was well aware of the tendency for on-task focus and behavior to denigrate quickly if

children were to be given unfettered liberty in the classroom. Consequently, Dr. Montessori tempered this propensity with what she referred to as “liberty within limits” by carefully structuring the prepared environment of the Montessori classroom (Montessori, 1912; Rambusch, 1962). A. Lillard (2007) contrasted this dynamic balance of freedom and structure in the Montessori classroom with more traditional classrooms by describing Montessori as having more structure at the macro-level (how the Montessori classroom is organized and how it functions), yet remaining relatively unstructured at the micro-level. The Montessori micro-level can be interpreted as the student level, in which students determine and build their own structure beyond the guiding structure of the didactic materials. Students are not expected to sit at a desk all day or while doing work, and they proceed with their work as “active and intelligent explorers” (Montessori, 1914, p. 138) according to their own developmental pace, abilities, and intrinsic interest. This view of children, in particular, is contrary to the expectations of children in most traditional classrooms –teachers typically expect students to be at their desks working concurrently on a teacher-specified task or lesson that is essentially identical for each student. The traditional curriculum is designed to move students together, lock-step through math hour, reading exercises, and so on with little regard for students’ individual liberty –an approach that was anathema for Dr. Montessori.

Also contributing to Dr. Montessori’s support and respect for the need of children to have liberty in the classroom was her contention that there are certain periods of time in children’s developmental sequence when they are more cognitively receptive, or “sensitive,” for acquiring and learning certain types of skills. Chattin-McNichols (1992)

reported that the ability of children to achieve fluency in their native language(s) by around age two was seen by Dr. Montessori as an especially representative example of a linguistic sensitive period. While the exact timing and duration of sensitive periods varies from child to child, the sequence of children's readiness for more cognitively complex tasks is invariant. The challenge pedagogically, therefore, is to follow the students' lead and align instruction as closely as possible with the timing of students' sensitive periods so that these opportune periods are taken advantage of. Dr. Montessori (1912, 1914, 1917) maintained that children themselves best know their state of readiness and, consequently, should have the freedom to explore for themselves what to work with among the didactic apparatus.

Taken as a whole, Dr. Montessori's background in both medicine and education combined to support her creation of an educational system that features a student-centered, student-directed, developmentally appropriate curriculum for young children. Additionally, this curricular approach, contrary to the accepted wisdom of the time, amply demonstrated the rich array of cognitively complex tasks that children as young as three years of age are fully capable of completing. From Dr. Montessori's conceptualization of child there follow some closely related implications for the role of the teacher in the Montessori classroom –implications discussed in the next section that contrast sharply with common notions of the teacher's role in traditional classrooms.

Role of teacher.

In order for Montessori students to experience liberty within limits so that students' true, natural potential as growing and maturing human beings can be fully expressed, the role, responsibilities, and function of the Montessori teacher must be well

coordinated with the unique set of dynamics that make up the Montessori learning environment. Central to this perspective is the radical role reversal for teachers of Montessori vis-à-vis teachers' traditional role in non-Montessori classrooms. In the traditional role, teachers are commonly perceived as older, wiser sources of "Truth" and dispensers of facts and information who imprint their knowledge onto the minds of younger, less experienced students (Montessori, 1915). Students, in this view, are perceived as passive receivers of such knowledge and are considered good students if they are able to store these bits of knowledge efficiently in their memory long enough to correctly recall and reproduce them on tests and exams. This passive model of the nature of mind and human learning is typified by John Locke's (1690) image of the *tabula rasa*, or blank slate. A *tabula rasa* model assumes that children's minds are waiting to be written upon by teachers or other holders of the "Truth." Similar, related metaphors of learner passivity include Comenius' rejection of the image of children's heads serving as receptacles for a large funnel lodged into the brain through which teachers "pour [knowledge] into their pupils" (Comenius, 1638, as cited in Doll, 2005, p. 31) and Popper's (1976) railing against the "bucket" theory of mind in which isolated facts and figures are idly collected in the empty buckets of learners' minds, waiting to be scooped out of the buckets at a later time.

Alternatively, Dr. Montessori (1912, 1914, 1915, 1917) asserted that children are active agents in the learning process, and that, when given the necessary time and opportunity to cognitively explore, children naturally discover the true state of their learning, including when the time is right for them to engage with more cognitively advanced work. The design and use of the Montessori didactic materials take advantage

of children's intrinsic desire for active exploration of their environment and are an integral component of the process that children go through in building their sense of readiness for their soon-to-be-experienced learning challenges. It can often seem to the casual observer that, in the Montessori classroom, the children appear to almost teach themselves through their engagement with the didactic materials. This is by design and one of Montessori's most noteworthy characteristics. There remains much room for the Montessori teacher to play an important role in children's learning processes; however, this role requires a substantial shift in approach from the historically ubiquitous teacher-centered approach of most traditional educational settings. Instead, an approach that is significantly more supportive of children as active creators of knowledge is clearly recognized within Montessori, a view that seems congruent with Popper's later assertions regarding the active nature of human knowledge building through the BVSr problem solving process (Popper, 1994, 1999).

In order to create a learning environment that supports the Montessori conception of children as naturally active agents in the learning process, Dr. Montessori (1915) argued that the role teachers play in the process must be significantly transformed, beginning with the acquisition of new attitudes. As Buckenmeyer (1999) pointed out, prevailing teacher attitudes have commonly revolved around teaching what adults think children should learn. Teacher control of the learning environment typically is maintained through verbal or written means, and teachers are "...habituated to the 'old' method of instruction through verbal presentation, so they presumed that learning occurred through external verbal transfer to the child as learner" (pp. 250-251). Dr. Montessori's (1915) concept for the "new" teacher is to only tell the child "...that which is necessary and the

teacher retires so as not to disturb the child with her own presence” (p. 74). Dr. Montessori further stated that this approach necessitates that teachers restrain the compulsive tendency “to intervene, to counsel, or to advise” (p. 64) so that the child’s natural learning process may emanate from within and not be constrained by well-intentioned, yet interfering adults. Dr. Montessori was under no illusions as to the difficulty of training Montessori teachers to develop these new attitudes –after all, these are attitudes that have been culturally endorsed in many societies for centuries. As Buckenmeyer (1999) highlighted, Dr. Montessori (1915) likened the process of learning to become a Montessori teacher as a personal journey of those “...who, having become monks, must discard all they have considered their former dignity” (pp. 64-65).

Dr. Montessori (1912) believed that Montessori teachers should be trained to develop and consistently utilize very refined observational skills so that teachers are closely attuned to the physical, affective, and verbal signals children display that indicate what they are experiencing with their learning. Teachers need to be able to read these signals and be ready to determine, for example, when teacher assistance or explanation is needed, when the learning challenges of a particular type of work have been exhausted and a child is ready for a new work presentation, or when a student simply needs only to be left alone to engage and explore. Curriculum development, in Dr. Montessori’s (1915) view, primarily “...concerns the finding of the [didactic] objects adapted to that age or that level of development which will provoke [the students’] attention and continued movement” (p. 170). For Dr. Montessori (1912), cultivating this ability required teachers to develop what she termed “the art of the educator” (p. 23). Montessori teachers are regularly called upon to make informed value judgments of when and how to pursue the

teachable moments with students and how to balance the individualized learning paths of students with classroom management concerns. Dr. Montessori (1914) admonished that a teacher should “...always continue to watch the children, never losing sight of their efforts, and any correction of hers will be directed more towards preventing rough or disorderly use of the material than towards any error which the child may make...” (p. 75).

To be effective in this kind of pedagogical role, Montessori teachers have to be able to “take a back seat” in the educational process and be patient, yet alert, in allowing students’ learning to naturally unfold without teacher interruption (Montessori, 1912, 1914, 1915, 1917). As Dr. Montessori (1914) stated, “‘Wait while observing.’ This is the motto for the educator” (p. 132). Dr. Montessori (1912) further explained that, “It is necessary, therefore, that the teaching skill be rigorously guided by the principle of *limiting to the greatest possible point the active intervention of the educator* [emphasis added]” (p. 231). Consequently, Montessori teachers act more as educational guides or coaches rather than according to the more traditional approach of teachers as controllers or directors of instruction. Chattin-McNichols (1992) further elaborated on the point of transforming preconceptions of what a teacher should be by asserting that Montessori teachers should not think of themselves as a cause of learning in children but should instead focus on their responsibility to remove obstacles to growth. One example of the degree to which Dr. Montessori believed in this necessary shift in teachers’ conceptualization of their responsibilities and approach to teaching was her decision to address the lead teacher in all Montessori classrooms as “Directress” rather than just “teacher.”

It could be argued, of course, that these types of teacher responsibilities are not appreciably different than what an experienced teacher in a traditional classroom would be doing. However, there is one major point of contrast in this regard that should be highlighted. As discussed in Chapter 1 of this dissertation, Kliebard (2002) asserted that, beginning with the early days of public education in America's one-room schoolhouses, teachers' primary responsibility has become keeping order. Dr. Montessori had a similar view, stating that in a traditional school environment, "...order is the first thing which the teacher would obtain in school. When she has succeeded in obtaining order, then she should begin to teach." However, in the Montessori classroom, with the support of the prepared environment and its didactic materials, as well as a teacher trained in the Montessori approach, "First, education begins and afterwards, as a consequence, order comes" (p. 154).

Montessori requires highly skilled teachers who are trained in everything from correctly utilizing Montessori's array of customized didactic materials to developing a complete understanding of how teachers are most effective in guiding children's natural propensity to learn. This includes efforts to help the new Montessori teachers understand how to dispel pre-conceived historical and cultural notions of what teachers should and should not be doing in the classroom. With few exceptions, Dr. Montessori did not delegate the responsibility for training Montessori teachers to anyone other than herself and a few trusted colleagues (Kramer, 1988). This became one of Montessori's strongest features: total quality control on a global scale with the originator and chief practitioner solidly at the helm. However, this practice also later proved to become the Montessori movement's Achilles heel. As Montessori grew exponentially more popular worldwide

throughout the first half of the 20th century, Dr. Montessori's insistence on personally training nearly every new Montessori teacher became increasingly difficult to achieve. Unfortunately, in the United States, this organizational growing pain, coupled with Dr. Montessori's unwillingness to develop a larger delegation of Montessori teacher trainers, contributed to the difficulties in establishing Montessori in the United States as an ongoing, mainstream educational system for parents and educators who were seeking proven alternatives to the traditional educational settings that were more readily available (Kramer, 1988).

While the discussion of what constitutes certifiable and complete training of Montessori teachers in the United States continues to be regularly debated, it is nonetheless clear that Dr. Montessori's vision of the role, responsibilities, and abilities that the "new" Montessori teacher should embody was well ahead of its time, and perhaps this is still the case. More to the current point, though, is the understanding of how the Montessori teacher complements Dr. Montessori's conception of child. The Montessori teacher simultaneously serves as a primary creator and integral component of the prepared environment. As will be discussed in the following section, the prepared environment is a complete, structured ecological system within which children are encouraged to freely explore, to make mistakes, and to learn from those mistakes as they engage with the scaffolded learning affordances that the prepared environment so richly makes available.

The prepared environment.

To step into a Montessori classroom is to enter what Dr. Montessori called the prepared environment, a learning environment that can seem simultaneously both

familiar and foreign to non-Montessorians. The most familiar aspects of the Montessori classroom for many observers likely include the lightweight child-sized tables and chairs that students can rearrange as they choose; the kitchen area with a low counter and sink; cabinets throughout the room that are sized for children's easy access to the stored materials; and a bright, welcoming orderliness about the room as a whole (A. Lillard, 2007; Saettler, 1990). Dr. Montessori was one of the first educators to insist that the design of the furnishings and layout of classrooms for children take into consideration children's small size and physiological need to be able to move around freely. Dr. Montessori (1912) railed against the "scientifically designed" student desk and bench seat that were screwed into the floor, with the bench seat carefully placed a standardized distance from the desk. She believed that such an arrangement only served the misguided interests of adults concerned with efficiency of instruction and with keeping children physically separated from one another for "...the prevention of immoral acts in the schoolroom" (p. 16). Dr. Montessori further asserted that this contributed to a debilitating learning environment "...where the children are repressed in the spontaneous expression of their personality till they are almost like dead beings. In such a school the children, like butterflies mounted on pins, are fastened each to his place, the desk, spreading the useless wings of barren and meaningless knowledge which they have acquired" (p. 14). The lightweight, mobile chairs and desks that Montessori uses instead serve an additional purpose beyond the more obvious one of being sized to match children's smaller stature. As is typical throughout the Montessori system, pedagogical purposes are carefully integrated into the design of the Montessori activities and teaching apparatus, with primary as well as secondary, or even tertiary, goals. In this case, Dr. Montessori (1915)

stated that "...these desks and chairs stand as exterior signs of freedom and a means of the child's education. One improper movement of the child makes the chair fall in a noisy way and the child receives evident truth of the error committed and of his own capacity. Yet, this very movement would not be noticed if the child were enclosed in the old-style desk. So, our child has a chance of self-correction and when he corrects himself, he will have clean and evident proof of his capacity" (pp. 364-365).

Today, it is not difficult to gloss over with little comment this seemingly minor feature of Montessori's prepared environment. Immoveable desks and chairs have mostly disappeared from the majority of America's classrooms, and many traditional Pre-K or Kindergarten classrooms today have a *prima facie* similar look and feel as the Montessori classroom. However, this similarity stands as a generally unacknowledged testament to the continuing influence that Montessori has exerted on general education classroom design in the United States. More to the central point of this paper's argument, though, is the degree of support shown in Montessori for a trial-and-error evolutionary epistemology at multiple levels of analysis. This support includes the apparently superficially mundane yet highly representative example of a child being given the freedom to learn from the noisy error of a classroom chair falling over. Dr. Montessori strongly supported the importance of environment as a scaffolded laboratory in which students have the liberty to explore and make mistakes as a normal part of their learning process. Further explaining this principle, she stated "...one of the greatest joys of humans is to be able to correct self and go towards perfection... The environment must simply be energetic in the denouncing of errors. The more this characteristic exists in the

environment of denouncing and exaggerating the errors, so much more does man develop these inner sensibilities and he begins to construct himself' (Montessori, 1915, p. 202).

What is perhaps a less familiar aspect of the prepared environment of the Montessori classroom is the degree to which the learning space allows for free student movement around the room. Montessori is, in essence, the original open concept classroom, with a near absence of individual student desks and the strategic use of its low cabinets to partition the room into areas that feature differing pedagogical purposes (Chattin-McNichols, 1992). The cabinets house a plethora of unusual looking learning materials that often have no easily discernable application. Additionally, students conduct much of their work on small lightweight mats that are placed on the floor in locations around the room. Students are free to stand, sit, or recline while working, and mats are rolled up and stored away when students have finished their work (A. Lillard, 2007).

Also noteworthy for many first-time observers of Montessori is the remarkably clean condition of each of the dozens of didactic materials and other items in the classroom. This high standard of cleanliness extends to the entire classroom as well, and is perhaps not surprising considering Dr. Montessori's emphasis as a medical doctor on good hygienic practices for children and adults alike. Furthermore, the numerous materials, many of which include small, easily lost parts, are organized and stored in neatly arranged, precisely ordered drawers and cabinets throughout the Montessori classroom. It was Dr. Montessori's belief that children learn best when the prepared environment's tangible components are spotlessly clean, in nearly flawless condition, and clearly well organized (A. Lillard, 2007; Montessori, 1912).

In addition to these tangible aspects of the prepared environment, a less tangible yet equally important component is those people who inhabit the prepared environment: the students, the teachers, and the students' parents. In particular, Dr. Montessori (1912, 1914) believed that the Montessori teacher greatly influences all aspects of the preparation and management of the learning environment. Specifically, the teacher's skills and training, philosophical approach to educational practices, and interactional style are all integral to creating a prepared environment in which students are empowered and encouraged to thrive. Dr. Montessori further professed an expanded view of what "environment" entails by maintaining that parents are equally important strategic partners with the Montessori teacher, the Montessori school, and the young scholars in attendance. From the first days of the original *Casa dei Bambini*, Dr. Montessori regularly included parents in training discussions devoted to further explaining the Montessori approach and her views on how parents could help support their children's growth and learning through Montessori-inspired "best practices" at home.

The intersection of the five components of the Montessori prepared environment identified in this part of the discussion –child-sized classroom furnishings, the freedom of students to move about the classroom without being confined to desks, the impeccably clean and orderly condition of the educational materials and classroom, the influence of the training and deportment of the Montessori teacher, and the role and responsibilities of parents in the greater educational process– are highly suggestive of a view of education that supports a holistic, open system approach. It is worth noting how, in this regard, Dr. Montessori's broad view of the prepared environment and the disparate interacting influences on children's learning anticipated subsequent descriptions of general system

theory as it relates to open feedback systems. Von Bertalanffy's (1950) comments on the interconnectivity of components or processes in such systems seem especially apropos: "You cannot sum up the behaviour [sic] of the whole from the isolated parts, and you have to take into account the relations between the various subordinated systems and the systems which are super-ordinated to them in order to understand the behaviour of the parts" (p. 148). Montessori's prepared environment is designed to be a purposefully created, scaffolded context within which children are expertly guided both at home and in school to easily explore their immediate universe, unimpeded by adult oriented contrivances like ill-fitting desks or furniture or by adult preconceptions of what and when to learn. This environment is respectful of children's need to establish regularities in routine and the ease of use of educational materials children choose to work with. All of the components of the prepared environment are designed with this goal in mind and are integral to the functioning of the system. A change in one or a missing link within the system is likely to affect other parts of the system and, ultimately, student learning.

It should also be noted that Dr. Montessori believed that children had a reciprocal role to play in terms of their influence on their surrounding environment. Dr. Montessori (1967) characterized children's role in society in part as that of "change agents" who held the promise of creating a better, more tolerant, respectful, and peaceful global society. This pacifist aspect of her philosophy was emphasized throughout the Montessori curriculum, and the optimistic theme of "children are our future" was a topic that Dr. Montessori spoke passionately about, particularly in the latter stages of her career (Kramer, 1988). It is likely that Dr. Montessori's views in this respect were shaped to a large extent by the times in which she lived, characterized especially by the personal and

career upheaval she experienced in fascist Italy during the early days of World War II. At first embraced by the Italian government, Montessori schools and their independent-minded founder grew out of favor as the government's control of educational policies and Italian society increased. Dr. Montessori moved around Europe, seeking a safe haven for herself and her schools, eventually settling in India for the remainder of the war. By taking up extended residencies, teaching, and training Montessori teachers in varied countries throughout Europe and south Asia, Dr. Montessori helped to greatly increase the popularity of Montessori education. Additionally, her message of the peaceful transformation of society through children's education was a message that fell on many sympathetic ears in a world consumed with conflict (Kramer, 1988; Standing, 1957). Although ancillary to the main argument presented in this paper, Dr. Montessori's body of work and professional activities that were devoted to fostering pacifism and educating children from all walks of life to be responsible custodians of the earth are themes that tellingly continue to resonate in the current era.

The interaction of the components of the Montessori prepared environment – tangible and intangible, subordinated and super-ordinated– creates a dynamic learning environment that fully takes into account Dr. Montessori's ideas concerning the conception of child and the role of teacher. The next section will extensively describe particularly representative elements of the Montessori curriculum and, in so doing, attempt to show the significant extent to which the other three aspects of Montessori discussed in this chapter –the conception of child, the role of teacher, and the prepared environment– are integrated into the design and operation of the Montessori curriculum.

The Montessori Curriculum

The Montessori curriculum, broadly conceived, is so thoroughly infused with Dr. Montessori's holistic philosophy towards learning, teaching, children, and environment, that it is sometimes difficult to analyze the Montessori curriculum as a distinct, quantifiable artifact. Certainly, there are explicit components of the curriculum that will be highlighted in this section as representative of Montessori's unique design. However, it is important to keep in mind during this curricular analysis that Dr. Montessori regularly expounded upon the contributing interactive role of the world surrounding the students as intimately connected with children's learning processes. This world extends beyond the didactic apparatus, the teachers, and the other students in the classroom to include the students' families, the natural world outside, and society as a whole (Montessori, 1917, 1967).

Student grouping, assessment, and the three-period lesson.

A discussion of the most salient components of the Montessori curriculum is best begun by first describing how Montessori schools are organized. In an apparent throwback to the rural schools of America's colonial past, Montessori classrooms are organized by multiple ages, albeit for very different reasons than the country schools originally prevalent in the United States. The Montessori early childhood classroom includes students from ages three through six. This corresponds roughly with the traditional Pre-K through Kindergarten grades. The Montessori elementary school includes children between the ages of six and twelve. The lower elementary classroom is for children aged six through nine, or the approximate equivalent of Grade 1 through Grade 3 in a traditional setting; the upper elementary classroom includes children aged

nine through twelve, or the approximate equivalent of Grade 4 through Grade 6 (A. Lillard, 2007).

The advantage of grouping multiple ages together in a classroom is twofold. First, students are with peers who share a range of similar developmental characteristics. Dr. Montessori made a clear distinction between the early childhood student with the greater need for sensorimotor learning, for example, and the elementary student who is developmentally ready for work that involves more extensive abstract learning (Montessori, 1912). This age distinction seems to make sense from a social perspective as well. While students in early childhood Montessori classrooms like to work side-by-side and to see what their peers are doing, they generally prefer to conduct their work independently. On the other hand, for students in Montessori elementary classrooms, the reverse is often the case. Students in this age group commonly socialize and work together in self-formed groups (A. Lillard, 2007).

The second advantage of mixed age classrooms is that the older, more experienced learners serve as role models or informal teachers for the younger, less experienced learners. This affords the younger students increased opportunities to observe what the older students are working on and previews the steps the older students have taken to reach mastery of more complex tasks that the younger students have yet to engage with. Older students may also be a source of informal corrective feedback to the younger students as the younger students go about their daily routines (Montessori, 1912; Saettler, 1990).

Also noteworthy of the Montessori curriculum is the absence of traditional exams and letter grades. This does not imply that student progress and accomplishment are not

explicitly accounted for, but that measuring student achievement is handled differently. Dr. Montessori was leery of many modes of extrinsic recognition of student accomplishment, believing that they could interfere with children's concentration and the natural expression of their intrinsic desire for learning (A. Lillard, 2007; Montessori, 1912). Consequently, it is rare to find gold stars, candy, and other commonly employed motivators of young children in a well-run Montessori classroom. Instead of exams and grades, lengthy progress reports are typically compiled that list the specific range of work tasks that are available in the classroom. Those tasks that the student has begun working on are checked off, and the date on which the task was first presented to the student is noted. This is often followed by a sliding scale that indicates the teacher's opinion of the student's current position relative to full mastery of the particular work. Space for any other qualitative teacher comments is also typically provided (W. Zeller, personal communication, February, 2008).

This type of assessment supports Dr. Montessori's view of learning as a developmental process that is not accurately captured by a simplified quantitative measurement such as the traditional letter grade. Additionally, it helps to demonstrate Dr. Montessori's depth of understanding of the positive correlation between intrinsic motivation and learning. Dr. Montessori warned that in most pedagogical systems, "...for the teacher conveniently to manage the classroom, it is necessary to enforce compulsory activities on the students. So, to enforce such immobile behavior on students who are condemned to be the teacher's listeners, the teacher must use abundantly a system of rewards and punishments" (p. 365). Such an understanding anticipated subsequent motivational research that has pointed to the potentially debilitating effects of

extrinsic rewards and punishments on student motivation and learning (see Deci & Flaste, 1995; Deci & Ryan, 1985; Kohn, 1993). Student assessment in Montessori attempts to avoid the motivational pitfalls of many traditional learning environments through its de-emphasis of unnecessary competition for grades and prizes.

Dr. Montessori observed that children, when given the choice of what to do in the Montessori classroom, regularly chose focused interaction with the didactic materials rather than more aimless play with a variety of toys that had been donated to the *Casa dei Bambini* and made available to the students. The students were initially attracted to the toys and tried them out but soon lost interest and went back to other Montessori work. This scenario, repeated over time with other groups of students, led to Dr. Montessori's (1914) contention that children have a natural inclination to take on challenges, concentrate, and pursue learning opportunities. Further, this innate interest need only be elicited at the right time through the prepared environment's organization of work and a skilled Montessori teacher's guidance for children's "liberty" in the learning process to express itself. Interestingly, it was the children's preference to work with the Montessori didactic materials that inspired Dr. Montessori to refer to all of the Montessori tasks as "work" to juxtapose children's preference for active engagement with the lesser engagement that mere "play" with ordinary toys provided (Kramer, 1988; Montessori, 1912).

In Montessori, lessons to students are normally presented individually: the teacher and one student only. Other students may look on and observe the lesson, and occasionally two students at similar stages of development may participate in a teacher presentation at the same time (Montessori, 1914). Nonetheless, Montessori teachers

typically deliver on a daily basis what many might consider the educational utopia of one-to-one instruction.

It is the teacher's responsibility to judge when a student has demonstrated mastery of a given work and is ready for a presentation of how to correctly use the next, more challenging level of work. Students are only allowed to work with the learning apparatus for which they have received a lesson from the teacher. Lessons are presented to students based on the three-period method pioneered by Seguin (1866) that he developed while working with "deficient" children placed in a special school for learning disabled children in Paris. The primary focus of the Montessori lessons is to demonstrate to the child how to correctly use the specific materials that Dr. Montessori adapted or designed (Montessori, 1912, 1914). The lessons usually center around two or three new objects so as to provide enough variation to interest the child but not be confusing (P. Lillard, 1980).

The lessons consist of three periods: naming, recognition, and pronunciation of the word. In *Period 1: Naming*, the teacher verbally provides the name of the object or the descriptor word to be learned so that the sensory perception can become associated with the name. Two examples are, "This is an ovoid" or "This is thick" (P. Lillard, 1980; Montessori, 1914). The objects to be examined are carefully pre-selected by the teacher so that the differences among them are initially only one dimension or attribute (Montessori, 1917). Later lessons may involve additional differences in degrees of various attributes, gradually proceeding from few stimuli with sharp contrasts to a greater number of stimuli with increasingly finer degrees of differentiation (Montessori, 1912). For example, Dr. Montessori (1914) instructed that, if the concept of shape is being studied, then the objects should be equivalent in size and color so that the child's

attention to the difference in shape is not distracted. If the concept of thick or thin is being studied, then the same also holds true and the teacher should select examples of thick and thin that are at opposite extremes. This lets the child examine samples of the apparatus that clearly show the thickest and thinnest versions of what is provided by the particular set of Montessori apparatus. Again, the emphasis is on allowing, at least initially, the differences to be easy for the student to recognize. P. Lillard (1980) provided an example of this pedagogical choice for Montessori teachers in the presentation of new letters of the alphabet: it is recommended to present a group of differently shaped letters like *l*, *m*, and *s* together rather than a group consisting of similarly shaped letters like *o*, *a*, and *c*. In *Period 2: Recognition*, the student is asked by the teacher to find the object corresponding to the name or to identify the object that displays the characteristic being presented. Phrases employed by the teacher might typically be, “Can you find the ovoid?” or “Give me the thick one” (P. Lillard, 1980; Montessori, 1914). The second period, as well as the first period, often needs to be repeated a number of times before proceeding with the third period, and there is no hesitation or impatience from the teacher for doing so. In *Period 3: Pronunciation of the word*, the teacher points to the object being studied or which displays the attribute being studied and asks, “What is this?” The purpose is to have the student demonstrate the ability to remember the name or characteristic corresponding to the object. If the student is able to successfully complete Period 3, then the student is ready to move forward in the sequence of related task variation and complexity (P. Lillard, 1980; Montessori, 1914).

Student errors throughout the three-step presentation process are handled in an understated manner by the teacher and, as needed, Periods 1 and 2 may need repetition.

In a significant departure from traditional instructional methodology, if a student does not seem to comprehend the learning point of the presentation, then instead of declaring the student's answers as wrong, the Montessori approach calls for the teacher to use this feedback as an indication that the student is not yet ready for the cognitive challenge the task poses. In this case, the presentation is quietly stopped, the student is free to move on to other already established work, and the lesson will be presented again at a later time when the teacher observes that the child appears more ready to comprehend the new task (Montessori, 1912).

Of particular interest is the manner in which Montessori treats error in this situation. First, there is no penalty for the student for not comprehending the new material –no failing grade or public embarrassment for not “getting it.” Instead, the presentation by the teacher is just one short episode for the student within an otherwise busy, productive day of engaged work. Second, there is no penalty for the teacher for having tried to present material that her “class” was not ready for. Stated another way, there is no implicit pressure to cover a certain amount of material in the class syllabus within a prescribed period of time. Instead, the Montessori system is remarkably open to not only students but also teachers conducting trials based on anticipated solutions to problems, eliminating errors as they occur, and retaining what is not in error as part of the knowledge accumulation process. Such is how the instructional system moves forward.

The Montessori approach is designed to coincide with and take advantage of the natural physiological and cognitive development of children, or what Dr. Montessori (1914) referred to as “psychical” development (p. 49). Dr. Montessori focused her method on three main skill areas: motor education, sensory education, and language. She

stated that, “The care and management of the environment itself affords the principal means of motor education, while sensory education and the education of language are provided for by my didactic material” (Montessori, 1914, p. 50). Dr. Montessori’s observations and pedagogical experiments with children of widely varying cognitive abilities, coupled with her understanding of Itard’s and Seguin’s prior research, convinced Dr. Montessori that sensorimotor work was critically important to learning, and that it functioned as the baseline from which later, more abstract and cognitively complex learning would proceed (Montessori, 1912, 1914, 1917).

Having looked at Montessori’s organization of the curriculum by age groups, its assessment practices, and its methodological approach to the presentation of new material based on the three-period lesson, the focus of the following four sections will turn to examining a few of the canonical examples of the Montessori didactic apparatus and their educational objectives drawn from the skill areas of motor, sensory, and language education. Many of these learning materials, or versions quite similar to them, are likely familiar to non-Montessori audiences, even though the materials’ Montessori origins may not be as well known because of their gradual integration over the decades into common use in many general education classrooms. This selected focus is not meant to diminish the importance of other areas of Montessori instruction. Practical life training and Montessori’s unique approach to teaching mathematics, for example, are integral components of the curriculum and very reflective of what makes Montessori Montessori. However, the selected Montessori learning materials presented next will serve as bellwether examples for considering how their use by young learners in Montessori

classrooms opens the door to an evolutionary epistemological analysis of their role in the Montessorian learning process.

Motor education and the wooden frame work.

Motor education refers to guiding or giving order to children's movements while being careful to not "... reduce the child(ren) to a state of immobility" (Montessori, 1914, p. 52). Montessori motor education includes developing what are termed Practical Life skills in such areas as movements of everyday life (handling objects, walking, sitting, rising), personal care (dressing), management of the household, gardening, and gymnastic exercises. Dr. Montessori (1912, 1914) described an emblematic example of personal care work: the set of wooden frames used for lacing and buttoning. This work, commonly known as the dressing frames, utilizes two pieces of cloth of equal size that are attached to a wooden frame, one piece attached to the left side of the frame, the other piece attached to the right side of the frame. Students are given a presentation on how to connect the two pieces of cloth in the middle of the frame using a variety of buttons, clasps, zippers, or laces (see Figures 1 and 2).



Figure 1. Wooden frame work: Bows (<http://www.nienhuis.com>)



Figure 2. Wooden frame work: Buckles (<http://www.nienhuis.com>)

As is the case with all Montessori didactic apparatus, there is more than one pedagogical goal to the work (Chattin-McNichols, 1992). In this instance, the primary goal is for young children to develop the fine motor skills necessary to attach the two sections of cloth. These motor skills are reinforced across the curriculum with other didactic materials, all towards the larger secondary goal of preparing children for the more complex task of holding a pencil and beginning to write. Additionally, the wooden frame work helps children develop the practical life skill of being able to dress and undress themselves. As can be inferred, this skill benefits children by helping them become more independent and, in so doing, more confident in their abilities.

Sensory education and the wooden cylinders work.

Montessori sensory education is designed to provide the means through which children refine their five senses and develop their ability to order, distinguish, and classify. The sensory materials are intended to display the attributes of objects such as dimension, form, color, weight, temperature, and texture. The materials are arranged in a graduated series, the order of procedure beginning first with the recognition of identities (the pairing of similar objects and the insertion of solid forms into places which fit them),

then recognition of contrasts, and finally the discrimination of objects which are very similar to one another (Montessori, 1914, 1915). Dr. Montessori (1917) asserted that while the objects themselves are important to this function, it is the qualities of the objects and their ability to highlight the desired attributes that are of primary importance.

The first sensory apparatus to be discussed is the set of four wood blocks with removable wooden cylinders that children from around the age of three typically find fascinating to work with. This didactic apparatus, also called the knobbed cylinders, is composed of a group of ten cylinders with varying diameters and heights that are fitted into corresponding cutouts in each of the four wooden blocks. When placed in the correct holes, the tops of the cylinders are flush with the top of the block. Each cylinder has a small wooden knob attached to the top that serves as a handle for picking up the cylinder. The ten cylinders in each wood block that make up this set of apparatus are arranged from left to right and vary dimensionally in a pre-determined sequence. Dr. Montessori (1914) stipulated that the different wood block sets should be ordered by the degree of ease with which children can successfully complete the task. The first block features cylinders that decrease in diameter only (see Figure 3 below) while the second block has cylinders that decrease in both diameter and height. The third block features cylinders that decrease in height only, and the fourth block utilizes cylinders that decrease in diameter but increase in height. The task calls for the student to take the cylinders out of the block and mix them up on a tabletop. The student must then put the cylinders back into the correctly sized cutouts without the cylinders falling and without making too much noise in the process.

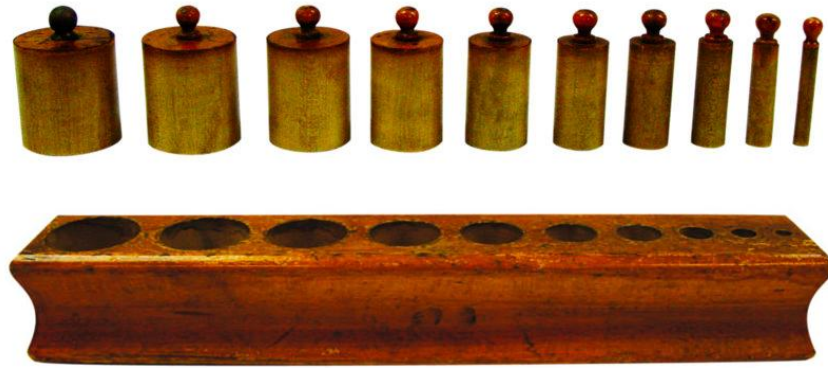


Figure 3. Wooden knobbed cylinders with equal height & decreasing diameter (http://www.nl.edu/library/archives/images/cylinders-feathered_2)

Students normally make numerous errors when they first begin to work with the cylinders, sometimes noticing the knocking sound of a loose cylinder against the walls of a hole that is too large for the cylinder's size, other times visually determining a mismatch very quickly. Dr. Montessori (1915) asserted that the challenge presented by the cylinders is such that students typically repeat the exercise multiple times with increasingly intense interest each time. As she described, it is not unusual for 30-40 trials to be made for students to reach the point of mastery and to feel fully satisfied with their accomplishment.

This state of intensity and single-mindedness of focused attention seems to reflect what Csikszentmihalyi (1990) termed "flow." In this view, a flow experience occurs when there is an optimum match between a student's current abilities and the intrinsically motivating challenges posed by the activity with which the student is engaged. For a student engrossed in such a moment, time can seem to race by, or alternatively, stand still, with actual minutes perceived as only seconds. As Dr. Montessori (1915) further described, "A child may be doing any work whatever and a hundred people may enter the

room and the child continues with his work as if nothing has happened. Someone starts to play the piano but the child does not notice” (p. 150).

Similar to the motor education example of the wood frame work, there are multiple pedagogical goals for this set of sensory work (Chattin-McNichols, 1992). According to Dr. Montessori (1912), the primary goal is to educate the sense of vision to distinguish differences in dimension. This will eventually lead to linguistic and mathematical work that introduces formal concepts of height, diameter, and shape. The left-to-right ordering serves as indirect preparation for left-to-right conventions in writing and reading, and the constant of ten cylinders per set subtly but directly prepares students for later, more explicit concepts of counting and the beginnings of base-10 mathematics. Finally, the knobs on top of each cylinder that children use to manipulate the cylinders are an example of how training the pincer muscles for future writing tasks is reinforced across the Montessori curriculum.

Sensory education and the wooden cubes, prisms, and rods work.

This next group of didactic apparatus comprises three sets of geometrical solid forms: wooden cubes, wooden prisms, and wooden rods. Having laid the groundwork for using these materials through the mastering of the wooden cylinder apparatus, Dr. Montessori (1914) asserted that students would be prepared for the cognitively more challenging trials of the cubes, prisms, and rods. In her opinion, this was because “...there is *no control of the error in the material itself* [original emphasis]. It is the child’s eye alone which can furnish the control” (p. 76) for recognizing differences in size among similarly shaped objects.

Dr. Montessori (1914) described the set of ten wooden cubes as pink in color with the sides of each varying in size from 1 cm. to 10 cm. The learning task is to construct a skyscraper-like tower on a small mat placed on the floor with the largest cube at the bottom of the tower (see Figure 4 below). The other cubes are to be placed above it in sequentially descending size so that the smallest cube is on top. Students are free to disassemble the so-called pink tower at any point in the construction process to try building it again.



Figure 4. Wooden cubes (<http://www.nienhuis.com>)

The wooden prisms are a set of ten rectangular shaped blocks, all of which are brown in color. Each is 20 cm. in length but with diameters that vary from 1 cm. to 10 cm. (see Figure 5 below). The learning task for this apparatus is to line up the prisms next to each other on a table so that they are sequentially ordered from either thickest to

thinnest or vice-versa to form what looks like a series of broad steps, hence the nicknames of the broad stair work or the brown stair work (K. DiGiacinto, personal communication, June, 2011).



Figure 5. Wooden prisms (<http://www.nienhuis.com>)

The ten wooden rods alternate in color between red and blue or may be colored all red instead of the original green (see Figure 6 below). Each rod is 4 cm. in diameter but varies in length by 10 cm. increments from 10 cm. to 1 meter (100 cm.). The learning task for this apparatus calls for the student to work on a mat on the floor and order the rods sequentially according to their length. Also referred to as the long stair or the red rods work, these rods, when correctly sequenced, resemble the row of pipes found on a traditional pipe organ.

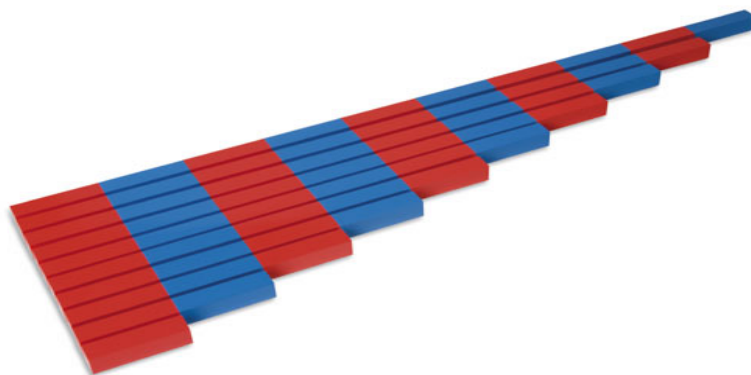


Figure 6. Wooden rods (<http://www.nienhuis.com>)

Dr. Montessori (1914) again emphasized that the teacher, after having presented the work to the student and having confirmed that the student has understood the desired end-state of the apparatus, should direct any further teaching only towards preventing “rough or disorderly use” (p. 75) of the materials and not towards providing any guidance or correction of the student’s subsequent errors. Stressing the need to allow for the right to uninterrupted repetition of the exercise, Dr. Montessori further explained that the student will be led “...sooner or later to *correct himself* [original emphasis]” (pp. 75-76). To facilitate this aspect of sensory education and the training of the eye to discriminate differences in size among similarly shaped objects such as the wooden cubes, prisms, and rods, Dr. Montessori reiterated that the differences among the objects should be immediately noticeable. This idea helps to explain why, in this case, larger-sized objects are utilized. Further, students should be adequately prepared for the cognitive and kinesthetic demands of the task that this series of didactic apparatus presents, hence the need for previous mastery of the wooden cylinder apparatus.

Throughout the period of time that students spend mastering the series of sensory oriented tasks described above, the students will also be presented with other related types of work. These other types of apparatus include exercises designed to develop children’s thermic (hot and cold), tactile (smooth and soft), and baric (relative weight) senses, and may sometimes include students being blindfolded to further isolate or enhance the non-visual cues. Dr. Montessori (1914) stipulated that the learning tasks associated with the education of the senses follow a prescribed order in terms of the learning goal of the tasks. Students must first learn to recognize identities so that, for example, they can pair together similar objects. Students then learn how to recognize

contrasts, in part by first being presented with selected extreme examples from a series or set of objects. This stage then leads to the final stage of learning how to discriminate among objects that are very similar to each other. Dr. Montessori noted that students working on educating their senses would typically begin to discover and then actively seek out examples from their surrounding environment that corresponded with concepts the students were learning in the classroom. Examples might be noticing varying colors in the sky, determining the names of geometric shapes of “found” objects lying about, and noting differences in the quality of surfaces of these objects when touched.

Language education and the sandpaper letters work.

As can be seen from the selected elements of Montessori sensory education described above, language education is extensively integrated into and, to a large extent, takes place simultaneously with the sensory work. When a student has recognized the differences in qualities of a given set of objects, the teacher always relates the idea of the quality being studied to the associated word, for example, “large” or “small.” Montessori teachers are trained to pronounce very clearly the sounds of the word that the child’s attention is to be drawn to, and the teacher’s volume of voice when presenting a lesson is typically very low, almost *sotto voce*. All of these factors help to train students’ “ ... attention to follow sounds and noises which are produced in the environment, to recognize them and to discriminate between them ... ” (Montessori, 1914, p. 123) with the aim of educating students to more accurately follow the sounds of articulate language.

As cited previously, P. Lillard (1980) reported how Montessori teachers use the three-period lesson to present students with new letters of the alphabet, making sure that the two or three letters introduced in a given lesson have different shapes so that the

contrasts among the letters are clearly highlighted. Dr. Montessori (1914) described how students are prepared for the act of writing through the three-period lesson by first beginning to work with what are called the sandpaper letters. This work features letters cut out of fine-grained sandpaper that are glued individually onto a larger, thicker card with a smooth surface (see Figure 7 below).

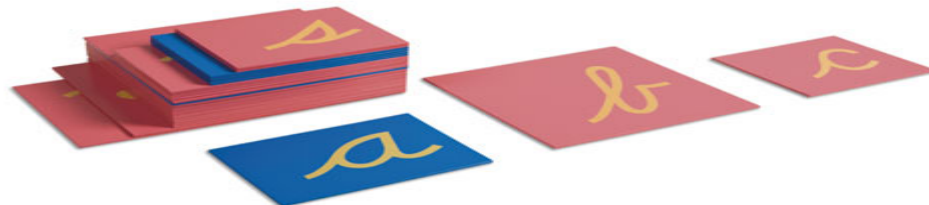


Figure 7. Sandpaper letters, cursive (<http://www.nienhuis.com>)

The teacher demonstrates how to lightly touch the letter using the tips of her index and middle fingers in order to trace the letter's outline using the correct movement. Then, the student traces the letter in the same manner while the teacher clearly pronounces the letter's sound. Note that, in this early stage, the teacher uses only the sound of the letter – not the name, for example sounding /l/ instead of saying “ell.” This activity serves to integrate both sensory training (touch) and motor training (tracing with the fingertips) with oral language recognition. An indirect but equally important goal of the activity is to mimic the act of holding a pencil for the transition into writing that is often not far behind the student's mastery of the sandpaper letter tracing. Additionally, this approach serves to teach reading in parallel with writing as the student “...retains the visual image of the letter” and “...when he recognizes them [letters] by sight he is reading the alphabet” (pp. 152-153). There are numerous other types of related didactic apparatus for building

language skills; however, this particular example is indicative of how Montessori students prepare themselves to first begin writing and then burst into reading.

Although there is comparatively greater involvement by the teacher in presenting the reading and writing didactic apparatus, Chattin-McNichols (1992) reported that the lessons are still kept short and clear. Students are free to move ahead at their own pace and always have the option of choosing to not do the work presented. Throughout the three-period lesson, the teacher uses feedback from the student to more precisely determine the student's readiness for the task and can quietly end the lesson if it appears that the task is not appropriately matched to the student's current developmental stage.

Montessori as Exemplar of an Evolutionary Epistemology

The above description of Montessori is intended to highlight the foundational principles and practices of the Montessori system of early childhood education. It is suggested that this description of Montessori can serve as a basis from which to examine the extent to which the primary principles of Karl Popper's evolutionary epistemology are uniquely embedded in the Montessori system. To help pinpoint this section's analysis of the apparent congruence between Montessori and Popper's evolutionary epistemology, it is useful to first summarize the key components from Popper's philosophy that could be considered most relevant.

Karl Popper advocated his theory of critical fallibilism as a potential solution to the Humean problem of induction. Popper (1934, 1963, 1976, 1994, 1999) asserted that knowledge consists of theories that are inherently falsifiable and that facts and apparent universal truths should be considered only provisionally acceptable towards approximating the truth. For Popper, those theories that assert greater empirical content

and have a correspondingly greater predictive power are more likely to be provisionally acceptable through a competitive process among theories that he termed verisimilitude.

What Popper referred to as “problems” arise when that which is held or anticipated to be true conflicts with that which actually occurs in the world. Attempts to resolve these dichotomies proceed through a process of trial-and-error elimination that he summarized in the schema: $P1 \rightarrow TT \rightarrow EE \rightarrow P2$. In this schema, P1 represents a problem or dichotomy first encountered. One or more tentative theories (TT) may be proposed as potential solutions to the problem. These theories, also referred to by Popper as conjectures, hypotheses, or anticipations, are then “put to the test” to discover the ways and extent to which they might be in error. The next stage, error elimination (EE), occurs when failed theories are eliminated; only those theories or parts of theories that survive rigorous tests are selectively retained. Inevitably, new problems (P2) are encountered, and the knowledge building process is repeated. Popper believed that new problems, however similar in nature and detail they might be to previous problems, are never identical because in P2 are contained the lessons retained, i.e. learned, from previous moves towards error elimination. Campbell (1974) characterized Popper’s theory of knowledge accumulation as a Darwinian-like evolutionary epistemology that proceeds through a blind-variation-selective-retention (BVSR) process. Central to this process is the testing of hypotheses against the environment without prior knowledge of what theories will prove successful in order to weed out those theories that are less well adapted to the specialized learning challenges that humans face.

It is also clear throughout Popper’s work that he firmly rejected the Lockean *tabula rasa* conception of mind in which learners’ minds are equated with blank slates,

passively waiting to be written upon by other more knowledgeable agents in the environment. Popper consistently argued for a much more activist interpretation of learning. In his view, humans are innately predisposed to actively explore and interact with their environment in order to seek regularities, form theories, and solve problems that aid survivability through the conducting of multiple trials and the elimination of error from those trials that do not succeed.

The Montessori model of active, autonomous learning.

If Popper's hypothesis is correct that learning requires active agents who create knowledge from within through interactions with the environment, rather than passive agents who wait for knowledge to be imprinted upon them from without, then it can be inferred that guiding students to become autonomous explorers and creators of their own understandings should be a priority for any formal educational system. To this end, Montessori seems especially noteworthy. As Dr. Montessori (1915) succinctly stated, "The fundamental basis of education must always remain that one must act for oneself. That is clear" (p. 173). The Montessori principle of fully encouraging the development of autonomous learning is integrated throughout all aspects of Montessori's prepared environment and pedagogical practices. From the very first days of their career in Montessori, students are given the liberty and autonomy to make choices for themselves regarding what, when, and for how long to interact with a wide variety of carefully scaffolded learning tasks. Additionally, students are never interrupted while engaged in the work of learning unless they are mishandling the didactic apparatus. Montessori teachers are extensively trained in how to create and support a rich, engaging prepared environment that is highly attractive to students and conducive for fostering a significant

degree of intrinsic motivation. Teachers are also adept at understanding how to guide students through the prepared environment towards learning apparatus that is appropriately leveled to students' readiness of the moment for the challenges of a particular activity. Moreover, teachers are skilled at doing so with minimal direct instruction so that there is no interference in children's naturalistic learning processes, especially the need that children have to "do it by themselves" without an adult looking over their shoulders and coaching them to watch out for an impending mistake. This approach of Montessori to fostering students' liberty within a scaffolded prepared environment is indicative of the type of self-directed adaptive learning that Bickhard (2001) described as a "...still more sophisticated process of developing knowledge about what counts as solving, or failing to solve, a problem, simultaneously with the processes of learning how to solve it" (p. 208).

From this perspective, it can be argued that Montessori closely aligns with Popper's epistemology. Montessori supports a curriculum and style of learning that is both student-centered and student-initiated. More knowledgeable others, i.e. teachers, are readily available to Montessori students for academic guidance. However, children's natural propensity to be curious about their surroundings creates a dynamic environment for naturalistic learning when students are given the freedom to conduct multiple trials towards mastering cognitively interesting tasks without fear of failure. The degree of responsibility accorded Montessori students to explore the prepared environment and, in essence, determine their own individual curriculum appears fully consistent with Popper's belief in the necessity of learners' active engagement with the world as part of the knowledge building process.

The emergence of knowledge in Montessori through the elimination of error.

In the course of exploring the environment and developing more autonomy as individual creators of knowledge, Montessori students inevitably discover that acting on their anticipations often leads to error. As Popper theorized, the discovery of error provides the opportunity to eliminate error and to move forward towards the identification of new problems. New problems suggest new hypotheses that, when tested, point to new potentialities for error elimination. On this view, it seems reasonable to assert that Popper's belief in the fundamental importance to human learning of discovering and eliminating error is thoroughly infused throughout Montessori at multiple levels. First considered in this section is an extended analysis of how the discovery and treatment of student error in Montessori through interaction with the didactic apparatus fits within Popper's philosophy of the logic of learning. Two subsequent topics in this section will examine the concept of error: first at the level of teacher and instruction, second at the level of Dr. Montessori and what was for her a Popperian-like bold experiment to create an educational system intended to complement naturalistic learning processes.

The discovery of student error through the didactic apparatus.

At the level of students' interaction with the Montessori didactic apparatus, the wooden cylinder activity previously discussed in this chapter is turned to first as an example that appears to evoke strong support for Popper's problem-solving view of knowledge building. Dr. Montessori (1914) stated that the child using this set of didactic apparatus "...first makes trials" and, in so doing, "...cannot help seeing his mistake in concrete form" (pp. 69-70). With this apparatus, a scaffolded BVS process that takes

advantage of explicit, direct feedback is utilized to select out the incorrect choices as students learn in which holes of the wood block to correctly place the cylinders. Dr. Montessori further asserted that, in this activity, the control of error resides in the material itself and that this serves to begin the process of auto-education that has since become a hallmark of the Montessori system. The built-in control of error in this apparatus aids children's developing ability to "...form judgments, to reason, and to decide" (p. 71). It is the teacher's responsibility to demonstrate to students how to correctly use the apparatus and explain what the solution to the problem should look like; however, "the desire of the child to attain an end which he knows, leads him to correct himself" (p. 71). The student anticipates the solution to the problem and actively engages with the cylinder apparatus to attempt to successfully solve the problem.

The distinction for Campbell (1960, 1974, 1997) was that the learning process moves forward blind to the ultimate solution to the problem. Montessori students understand what the end-state to the problem, the wooden cylinders in this case, is supposed to be, and they will make various attempts to put the cylinders back in their respective correct cutouts to arrive at this goal. Those attempts that succeed will be retained, those that do not succeed will be selected out. Additional attempts will be made until the student has learned how to correctly identify which cylinder exactly fits each hole in the wood block. As Bickhard and Campbell (1996) claimed, "Constructions cannot *require* [original emphasis] foreknowledge of what to construct...they must be blind. They must involve trial-and-error, variation and selection...In short, learning and development cannot be understood without adopting an evolutionary epistemology" (p. 124). Knowledge builds through the accumulation of repetitive moves towards

successfully reducing the instances of error and, ideally, avoiding error completely. In this case, the wooden cylinder apparatus provides immediate, concrete visual and tactile feedback to the student regarding which actions avoid error and, ultimately, lead to successfully completing the task.

In the wooden cubes, prisms, and rods series of didactic materials previously discussed, the locus of control shifts significantly away from the materials themselves and more towards the learner, thereby making this series of apparatus somewhat less autodidactic-centric and more cognitively challenging than the wooden cylinders. However, the learning affordances provided and the overall activity's design also seem to strongly support Popper's notion of a trial-and-error system of knowledge building. Students interact with the cubes, prisms, or rods with an anticipated goal in mind of what a successful solution to the problem should look like but they proceed in a manner that is blind to possible answers for how to solve the problem. Again, similar to the wooden cylinders, students must put their conjectures to the test. Those variations that appear to succeed are retained while those that appear to have failed are selected out as students' attempts to correctly align the blocks move further away from error to the space in which there is no further error to select out. This allows the knowledge accumulation process to move forward through an iterative process of refutations and error elimination and promotes the clarification of new problems (P2) that will be followed yet again by new proposed conjectures or tentative solutions (TT) and further error elimination (EE).

The example of Montessori language education provided, the sandpaper letter activity, also is conducive to a Popperian BVSR analysis. Through the senses of both touch and sight, students are provided immediate feedback as to how accurately they are

able to trace the sandpaper letters with their fingers. Some preliminary feedback from the teacher may be necessary to ensure that students' movements follow the desired motion for "writing" the letters. However, students must learn when to select out those moves that are in error and do not correspond with accurately tracing the letters while retaining those sensorimotor solutions that do correspond with accurate tracing. Multiple trials and multiple errors form the base from which students' understanding and ability to successfully complete the task grow. The sandpaper letter apparatus is designed to scaffold students' learning trajectories by constraining the types of error that students can experience in ways that provide feedback that students are developmentally able to comprehend and assimilate.

Each set of scaffolded didactic apparatus in Montessori presents a unique blend of previously learned solutions to similar problems and not-yet-tested tentative solutions to new, more cognitively challenging problems. Bickhard and Campbell (1996) captured Dr. Montessori's pedagogical insight by stating that "...old, already solved problems never recur in exactly the same form. So, old solutions from old situations must somehow be generalized to fit new particular situations" (p. 138). The allowance for error in the learning activity and the freedom to explore alternative theories that may be less error prone, all the while unhindered by outside intervention from teachers or peers, would seem to strengthen the argument that Montessori provides young children with a remarkably robust evolutionary epistemological learning environment. Moreover, Montessori clearly seems to evidence not only a significant degree of trial-and-error, BVS learning but also a carefully crafted interplay between variation possibilities and selective-retention processes. Bickhard and Campbell (2003) cautioned that, "Variation

and selective-retention are at odds: too much variation...and there is no retention... Too little variation...and there is no opportunity for an emergent order” (p. 217). Montessori heeds this warning by providing its students with what arguably appears to be an ideal balance in the didactic apparatus between the liberty for exploring its rich cognitive challenges without excessive variation possibilities and the scaffolded opportunities to learn from error while selectively retaining those moves that are judged to succeed. Through this process, an emergent order of knowledge building can then proceed.

Montessori teachers, instruction, and the discovery of error.

Montessori’s encouragement for the active discovery of error is infused throughout the entire educational system. As such, it extends beyond the focus of most traditional educational approaches that tend to emphasize only the discovery of student error. In Montessori, for example, at the level of teacher and instruction, it is clear that regular opportunities are provided for “trying out” behavior by teachers when presenting students with lessons on the use of new didactic material. Montessori teachers are extensively trained to recognize the often subtle signs that children display when they have mastered the challenges of a given set of work and are ready for a presentation of more cognitively advanced work. There is an anticipation, or conjecture, by the teacher towards a solution to the problem of when is the right time to present a new task. However, there is no guarantee that the teacher is correct, and the teacher’s conjecture may be refuted –the child may not yet be able to comprehend the task’s requirements even after allowing for multiple trials during Periods 1 and 2 of the three-period lesson. The teacher’s theory is put to the test and may be shown to be incorrect. In such a case, the error is eliminated (the lesson is quietly ended), the child is free to pursue other work,

and a new problem situation (P2) is identified: the lesson will need to be presented again at a future time that the teacher anticipates will be more closely aligned with the child's state of readiness.

Certainly, teachers in traditional educational environments often exhibit trying-out behaviors when presenting new material to their respective classes in order to determine students' comprehension of a given teaching point. Utilizing various types of student feedback, including quizzes and exams, teachers may modify their lesson plans and syllabi to align more closely with their classes' collective ability to accomplish the desired learning tasks. However, at the grass roots level of teacher/student interaction, Montessori seeks to exploit fully the trial-and-error dynamic of student readiness for learning by having teachers individually present a new task to students, potentially multiple times. Again, the Montessori teacher may misjudge a student's readiness for learning a given new task but this error on the teacher's part is not pejorative and does not either positively or negatively affect other students or the "class syllabus." Instead, this error provides informative feedback to the teacher that is useful for the identification of a new Popperian P2 and, in a larger sense, is integral to facilitating the teacher/student dynamics of the Montessori prepared environment.

The creation of Montessori through the discovery of error.

After over a century of successfully educating multiple generations of children throughout the world, it is perhaps easy to take Montessori somewhat for granted and to forget that there was no Montessori before Montessori. Dr. Montessori began her Popperian-like bold experiment with creating an educational system for young children with low socioeconomic status but normal intelligence after she witnessed the remarkable

educational achievements of special needs children she had taught utilizing techniques and materials originally pioneered by Seguin and Itard (Montessori, 1912). The unexpected problem (P1) that Dr. Montessori noticed was the superior scores that some of her special needs students obtained on an entrance exam for public school in Rome compared with the lower scores of other children of normal intelligence taking the same exam (Kramer, 1988; Montessori, 1912). Dr. Montessori hypothesized that the problem was primarily pedagogical, not medical, and she put her conjecture (TT) “to the test” with the establishment of the first *Casa dei Bambini* in 1907. Thus began her decades-long experiment.

As previously reported, the *Casa dei Bambini* began with little more than Dr. Montessori’s conjectures and the barest of materials and furnishings. Her resourcefulness for acquiring classroom materials was perhaps tested as much as her ingenuity in adapting Seguin’s materials for children of normal intelligence and in creating materials of her own. The larger point to be made, though, is that Dr. Montessori’s remarkable acumen and tenacity in observing how her students worked with early versions of the didactic materials enabled her to note what aspects of the interactions were in error. Carefully and consistently over her long career, Dr. Montessori sought to perfect the practices and materials utilized in her educational system. In this case, “perfecting” can be thought of as analogous to eliminating the error (EE) she discovered while selectively retaining those parts of her emerging educational system that, in her view, succeeded. The result extant today, it can be asserted, is a robust example of a time-tested educational system for young children that embodies the acquired knowledge gained through the continual elimination of error in an applied BVSR learning process.

Montessori, on this view, can be accurately characterized as fundamentally evidencing to a significant extent an applied Popperian evolutionary epistemology.

To conclude, if the assumption is made that Popper's evolutionary epistemology avoids the logical fallacies inherent in the inductivist account of knowledge accumulation and that the extension of his philosophy as a BVS process can serve as a likely explanation for a naturalistic human learning process, then it can be reasonably asserted that Montessori's demonstrated success in formally educating children as young as three years old across differing cultures, languages, and socioeconomic circumstances worldwide reflects a working model of an applied Popperian evolutionary epistemology. To the extent that this assertion is accurate, it implies that a combined Popperian-Montessorian perspective may be fruitful for suggesting certain key principles for guiding future educational reforms that are intended to create formal learning environments organized around facilitating and enriching student learning. The next chapter summarizes these guiding principles and will discuss how a framework for an improved model of education that is applicable to other contexts could be derived. Applications of these suggested reforms will be presented with an eye towards honoring Tyack and Cuban's (1995) admonition of the entrenched power of the grammar of schooling. In accordance with the authors' views, keeping the awareness of the grammar of schooling in mind should then afford suggested reforms, whenever possible, the greatest opportunity to be successfully integrated into existing educational structures.

Chapter 4: The Education-as-Evolutionary Epistemology (EEE) Model

From the previous chapter's discussion of the principal perspectives and components that make up the Montessori system and how it exemplifies an evolutionary epistemology, there emerge guiding principles for curriculum and its concomitant cousin assessment that can now be cogently articulated. This chapter explains in its first three sections how all of these components combine to form a single, highly integrated, yet flexible education-as-evolutionary epistemology (EEE) model for educational reform. The first section details the proposed learning environment's organizational structure. The second section then discusses the interlocking roles of the environment's participants. The chapter's third section presents the model's provisions for reconceptualizing approaches to curricula and student assessment.

Structure and Organization of the EEE Learning Environment

Creating a learning environment grounded in the Popperian/Montessorian perspective that encourages a typical 14-year-old female student to explore diverse methods of testing for and discovering error necessitates the coordinated interaction of a number of components. For example, she will need regular, uninterrupted periods of time each school day throughout an extended school year that are consistently long enough for her to pursue her learning interests with focused continuity. Equally important for this prototypical student's learning is that she be grouped with learners who share a similar range of developmental stages so that she can both learn from and teach other students within her group. Additionally, the furnishings and technology in her classrooms will need to provide concrete supports for her learning within the environment. Specific

guidelines for organizing her learning environment to address these needs within the EEE model are described in the following five recommendations.

Recommendation #1: Increase the number of school days per year to provide greater continuity for student learning.

Gandara and Fish (1994), St. Gerard (2007), and others have argued that learning is an ongoing, life-long process that does not end with one's final steps across the stage at graduation and that formal education should be more constructively conceived as a year-round activity. Growing minds, especially, should not be tacitly encouraged to "turn off" for two to three months each summer. The resulting pronounced dip in many students' achievement levels upon their return to school each fall, often referred to as the "summer slide," requires that much time and effort be devoted to reviewing and relearning many of the previous school year's lessons. In particular, this has been highlighted as a special concern for populations of at-risk students (Borman, Goetz, & Dowling, 2009; Celano, & Neuman, 2008). Instead, the time and effort spent relearning last year's lessons could be more productively directed toward investigating new learning problems provided that the academic calendar were designed to support year-round schooling.

Therefore, the EEE model's first recommendation is to re-examine the anachronistic schedule of the traditional school year calendar with the intention of extending it beyond the typical nine-month school schedule (see 180-day example at www.beth.k12.pa.us/calendar). Well-coordinated, extended breaks from schooling so that students, teachers, and parents can refresh and reinvigorate themselves should certainly be a part of all school calendars; however, in today's post-industrial information age, there is little justification for the agrarian-era practice of metaphorically sending school-

age children out to the field for weeks at a time with no organized academic activity. American society and the types of careers that most Americans pursue have become more diversified and less season dependent, and the quality and comfort of many school buildings have improved or could be improved in the near term to better support consistent utilization (Chaney & Lewis, 2007). Year-round learning, on this view, is both practical and well rationalized.

Specifically, the EEE model recommends increasing the number of school days per year from current average minimums of about 180 days or 36 school weeks to 210 days or 42 school weeks. This would allow the academic year to be divided into three 14-week sessions of Fall, Spring, and Summer semesters, thereby mirroring the typical length of most university semesters. Doing so would increase total annual formal study time by approximately 17% over current minimum norms and would provide students with greater continuity of learning focus and attention over the entire calendar year. The remaining ten weeks in the annual calendar would be available for time off from scheduled study and apportioned to include three weeks each for winter and summer breaks, one week each for fall and spring breaks, and up to two weeks total for national holidays such as July 4th and Thanksgiving.

Recommendation #2: Revise daily instructional schedules to allow for longer periods of uninterrupted learning time.

Longer periods of time each day in which to study without the interruptions of changing classrooms or teachers, public address announcements about upcoming school events, and the like are integral to the EEE model. Montessori offers instructive guidance in this respect with its three-hour study periods, called work cycles. Dr. Montessori

(1914) noted that three-hour, non-interruptible work cycles respect students' need to focus extensively in their areas of inquiry without feeling as though their work-of-the-moment is summarily cut short. In a similar vein, some mainstream school systems have successfully incorporated so-called block periods of approximately 90-minute classes into their daily class schedules. Although the academic gains students realized after block scheduling was introduced have been reported as mixed (Lawrence & McPherson, 2000; Veal, 2000), the recommendation of the EEE model is to build on the momentum already established by incorporating the three-hour Montessori work cycle as part of a comprehensive model that addresses all facets of the educational process.

A revised daily schedule could be based on the example outlined in Table 1 below. Potential logistical difficulties such as scheduling lunch for all students at the same time or extending the instructional hours until later in the afternoon may need to be reconciled with current routines; however, the model's schedule features two non-interruptible Montessorian-like work cycles per day. Ample time is provided before the school day begins and between the morning and afternoon work cycles for food, physical exercise, individual study, daily announcements, and other school business.

Table 1

Example of Daily Work Cycle Schedule

Time	Activity
8:30 – 9:00	Student arrival, announcements, individual study, exercise
9:00 – 12:00	Morning work
12:00 – 1:00	Lunch & exercise
1:00 – 4:00	Afternoon work

Recommendation #3: Group students heterogeneously to capitalize on advantages of mixed-age classrooms.

The current practice of grouping students homogeneously by same-age grade levels dates to the common school reforms of the late 19th century that sought to standardize the then hodgepodge system of mostly rural one-room schoolhouses (Kliebard, 2002). However, arbitrarily grouping same-age students together, while satisfying the adult priority of administrative efficiency, does not best serve students' learning interests or proclivities. Instead, the EEE model recommends grouping students heterogeneously by age to correspond with the Montessori practice of placing together students of approximately three years' difference who generally exhibit similar developmental characteristics. As described in the previous chapter, this Montessori practice takes advantage of the tendency for older, more mature students to serve as role models and informal teachers for younger, less mature students.

Mixed-age classrooms also provide enhanced support for a more student-centered, student-responsive curriculum in which responsibility is shared for cultivating good learning practices and establishing accepted social norms within the classroom. This, in turn, fosters a less teacher-centric learning dynamic and helps to reduce the pressure that teachers often face ensuring that all students are pedagogically well tended to in a large classroom. New grade level designations that refer more broadly to the mixed-age schools and groups can be formulated that do not use implicitly pejorative hierarchical categories such as "lower," "middle," and "higher" or "elementary" and "junior." This is suggested to help minimize unnecessary perceptions of students' position relative to other students or segments of the curriculum, as illustrated in Table 2 below.

Table 2

Example of Student Grouping by Age and School

School Level	Student Ages	Name of Group
Childhood	3-6 years old	Childhood
Youth	6-9 years old	Early Youth
	9-12 years old	Youth
Adulthood	12-15 years old	Early Adult
	15-18 years old	Young Adult

School systems following this model would comprise three different schools with students placed in groups according to the progressively more sophisticated developmental capabilities that approximate each age group. Students at the Childhood level, aged three to six, developmentally mirror those students in Montessori early childhood programs or in mainstream classes of early Pre-K through approximately first grade. The Youth level contains two age groups with the first group of students aged six through nine designated as Early Youth, and the second group of students aged nine through twelve designated as Youth. The Adulthood level follows a similar pattern with a younger group of twelve to fifteen-year-olds called Early Adult and an older group of fifteen to eighteen-year-olds referred to as Young Adult.

Recommendation #4: Design learning spaces that are intriguing, comfortable, and flexibly configured to suit multiple learning styles and purposes.

The EEE model draws inspiration from Montessori for its recommendations regarding classroom layout and furnishings. Classrooms should be bright, welcoming, and impeccably clean. Dr. Montessori (1912) emphasized the importance of sparking

students' interest to explore the learning environment by making sure that learning materials are kept in perfect working condition and are as visually appealing as they are cognitively intriguing. Orderliness is especially critical so that regularities of easily locating and accessing the learning resources available in the classroom can be encouraged and developed.

Students should have the ability to freely move around the classroom space as seems natural or comfortable so that they can work while standing, sitting, or reclining. The furnishings literally support the students while they are working, and should also metaphorically support their personal style of working in a few important ways. All furnishings must be size-appropriate to the age group of the students using them, much as clothing, for example, is differentiated by size and age group in a department store. Work areas should have the ability to be easily and flexibly configured to accommodate students who may be working individually, in a small group, or as an entire class. This requires that the tables, chairs, and individual desks provided should not only be sturdy and comfortable but also lightweight and have wheels on their legs so that they can be moved easily by the students to suit the work purpose of the moment. Cabinets for storing resources and other study materials, again, should be size appropriate and conveniently located to allow for quick and easy access to their contents.

Recommendation #5: Use educational technology to complement students' natural ability to identify problems, formulate tentative theories, and eliminate error.

Saettler (1990) described educational technology as a process or system of practical knowledge that has been developed over many centuries through trial and error,

practice and imitation, and particular moments of great individual creativity. The author further asserted the importance of distinguishing between the process of developing a technology of education and the utilization of products or media as part of a specific technology of instruction. The challenge often seems to be not only how to distinguish these two components of evolving technology but also how to incorporate both components into an educational model to strengthen its philosophical relevance and pedagogical integrity without inadvertently succumbing to the allure of adopting the “next big thing” that promises to solve education’s most pressing problems. As an example, Montessorians continue to debate up to the current day the extent to which newer didactic apparatus and modern instructional technologies, computers in particular, should be incorporated into the Montessori prepared environment (see A. Lillard, 2011 for an extended analysis related to this point). However, considering the ubiquitous presence of computers, the Internet, and other evolving technologies in modern-day life, many of which show promise as valuable learning resources, it is incumbent upon the EEE model to advocate for the solid presence and active role of newly developed educational and instructional technology in the evolving activities of the contemporary learning environment.

Because of the frenetic pace of technological innovation and change that characterizes the current era, though, any specific technological recommendations made in the EEE model are likely to become quickly outdated, if not obsolete. For this reason, the model more prudently focuses on suggesting a fundamental guideline that seems consistent with a Popperian/Montessorian-based educational framework. The central point is not whether any given type of technology is, in and of itself, good or bad but

rather the extent to which students and teachers understand how it can be used effectively in an educational environment to complement students' ability to identify problems, formulate tentative theories, and eliminate error. To the extent that a particular educational or instructional technology can be well understood in this sense and is likely to be advantageous for students' trial-and-error learning processes, then students should be given opportunities to explore its learning potentialities in a manner similar to all other didactic apparatus and learning resources. Teachers should present the technology to students when students exhibit signs of readiness for utilizing the technology's learning affordances, making explicit the ways through which the new technology might add greater capabilities to students' efforts to test their learning hypotheses. This should hold true in particular for the products and media of instructional technology provided that the technology made available in the classroom is always kept in perfect working order, is highly accessible to all students, and is easily moved around by students to complement their individual working styles.

New Roles for Participants in the EEE Learning Environment

Other less tangible but vitally important influences in the EEE learning environment for the 14-year-old female student described earlier include the training, experience, philosophical approach, and pedagogical role of her teachers in the educational process. Beyond the immediate classroom environment, her family members also have a valuable supporting role to play through fulfilling their responsibilities within the educational enterprise. This section provides guidelines for these roles as conceived within the EEE model and will suggest ways in which all members of the EEE learning environment should be trained for the expectations that these reconfigured roles demand.

Recommendation #6: Shift the paradigm of “good” teaching from transmitting facts to facilitating student trial-and-error problem solving.

The EEE model supports bolstering students’ self-confidence and motivation to learn through a Popperian process of seeking error to be eliminated while testing their boldest theories. This requires that fears of failure or penalties for making mistakes must be removed from the learning environment. It is also necessary for teachers and all other participants in the educational community to retreat from any entrenched theoretical or pedagogical positions that might obstruct students’ trial-and-error elimination process of learning. The onus is clearly on the adults for developing Montessorian-like flexibility and patience while adapting to the nonlinearity of students’ learning interests and developmental processes so that students are not unwittingly or implicitly pushed to hurry up or follow only straight lines of inquiry. Because the shape or pattern of students’ learning trajectories often resembles a compendium of seemingly disjointed and illogical yet interacting components, the teacher’s role must move away from the well-intentioned but incorrect traditional notion of intervening to “impose order” by transmitting bodies of facts and figures into the minds of passive receivers of information (see Perkinson, 1984, 1993 for a related discussion). Instead, the EEE model calls on teachers to become facilitators of learning opportunities and resources that students can utilize beneficially as they move through what can often appear as a murky, disorganized learning process.

To accomplish this reconceptualized role for teachers within the EEE learning environment, the model references Dr. Montessori’s (1915) view that prospective teachers will likely first need to unlearn many of the unproductive learning attitudes and

habits they acquired throughout their own years of schooling that do not support the principles outlined in this model. Therefore, the EEE model advocates that all teachers-in-training pursue significant guided reflective thought and critical examination of conscious as well as unconscious assumptions regarding both teaching and learning. The recommendation is for all teachers to achieve a high quality standard of specialized professional training that supports a Popperian/Montessorian-based pedagogy as outlined in the following two recommendations.

Recommendation #7: Require a three-year graduate teaching degree with advanced interdisciplinary course work to be licensed as a professional practitioner.

The EEE model recommends reforming teacher training to provide pre-service teachers with the same kind of specialized training that those training for the medical and law professions receive so that pre-service teachers grow to become professional practitioners who are fully capable of facilitating each student's naturalistic learning process. The EEE model stipulates that a professional graduate degree should be achieved by all teachers before they are licensed to practice their profession. This degree should include required advanced course work not only in subject knowledge and pedagogy, skill areas already normally part of most graduate level teacher training programs, but also additional instruction in other closely related disciplines that are not always included or emphasized. For example, being well acquainted with the history of the development of educational systems and how they have changed over time, or not, to meet the challenges of the era is valuable for understanding and contextualizing the current era's educational dilemmas, priorities, and politics. Learning about philosophy over the millennia and the ageless questions related to knowledge, logic, ethics, and

humanity is vital for articulating a compelling personal philosophy of teaching and learning. Studies of cognitive science, biology, and psychology should be included so that teachers-to-be are well informed of the most recent research regarding learning processes and the functioning of the human mind/body relationship. Specialized course work that focuses on best practices for teaching non-native speakers of English and students with learning differences and other special needs is likewise necessary so that teachers can provide the customized assistance needed by learners who may, at least initially, be less able to fully participate in the educational enterprise.

The EEE model anticipates that revising teacher training programs to integrate all of its recommendations related to pre-service training will lengthen the time-to-degree horizon for students from the current two years to three years. However, this would mirror the length of degree programs found at most law schools and some medical or pharmacy schools. The additional financial burden of a longer training period would hopefully be offset over time by teacher salaries that should increase to equal those of other similar professionals in medicine and law. The EEE model also anticipates that the increased academic rigor of teacher training may possibly eliminate some students who do not exhibit the dedicated effort and motivation necessary to be successful in such a demanding profession; however, this winnowing-out process would not be unlike similar situations regularly found in law or medical schools.

Recommendation #8: Institute a one-year post-graduate professional teaching residency.

Similar to the extended training period of the medical profession, the EEE model requires that teachers should successfully complete a paid residency of one complete

academic year before becoming eligible to be licensed as a professional teacher. During this residency, pre-service teachers would extensively observe other senior teachers and they would practice teaching while being guided and evaluated by experienced teacher trainers. A similar precedent for a mandatory period of student teaching already is in place in most, if not all, teacher training programs. The EEE model builds upon this current practice by extending the period of supervised field training so that it parallels the rigor of the residency period most physicians must complete.

An additional stipulation of this requirement is that at least half of the residency be conducted in a school setting composed primarily of students from socioeconomic, linguistic, cultural, or religious backgrounds that differ significantly from that of the teacher-in-training. Although Montessori in the United States today tends to be mostly available in private school settings to students from families that typically have the financial means to afford the additional cost of a Montessori education, it should be remembered that Montessori's roots are deeply embedded in the social advocacy of educating cast-off children from the slums and mental asylums of Rome. The type of residency proposed in this model takes inspiration from Montessori's activist beginnings and proposes that all teachers, regardless of personal background, should be professionally committed and extensively trained to help students from all walks of life learn to the best of their natural abilities.

Recommendation #9: Educate families for their participatory role as supporters of their children's learning.

Similar to the new role for and training of teachers in the EEE learning environment, the model calls for a revised role for and explicit training of parents and

other concerned family members. The EEE model assumes an active role for all participants in the educational community, and parents are responsible for engaging with their children and their children's teachers to learn how to support their children's learning activities both in school and at home. Teachers and school administrators should regularly communicate with parents through email, phone calls, and letters sent home, and seminars and small group conferences should be held to explain more details of the principles, practices, and activities of the EEE learning environment. Students should demonstrate the projects they are working on and describe how these projects are connected with their efforts to solve Popperian-type problems and eliminate error. Parents should be required to participate in at least one school event or daily school function per 14-week academic session to maintain a strong connection between families and other participants in the EEE learning environment. Accommodations for parents' personal situations or other life responsibilities may need to be made on a case-by-case basis; however, the model's priority for parents' active engagement and support for children's learning beyond the confine of the classroom is clear. Because effective communication is critical to forging the school/home relationship, in those instances when parents or family members do not have adequate English language skills to comprehend topics of discussion or to communicate their thoughts, interpreters and translated documents should be planned for and incorporated, as needed, into all communications and seminars or conferences.

Designing Curriculum and Assessment in the EEE Learning Environment

The curriculum that the EEE model advocates for the female student mentioned in preceding sections should be firmly based in a Popperian/Montessorian framework and

should call for all members of the educational community to trust her insight and give her the primary responsibility for formulating curricula that she initiates and investigates. Heeding Burgess' (1977) advice that, "All educational planning and organization should *start from* [emphasis added] the individual student" (p. 171), the EEE model presents its recommendations for infusing curricula with greater authenticity and flexibility so that formal plans for learning will more closely match each student's individual needs, aspirations, and problem formulation processes.

It frequently remains the case in mainstream education that acceptable pedagogical approaches revolve around lock-step lessons for entire classes, pre-determined scope-and-sequence type syllabi, and the overwhelming desire of adults to move the syllabus forward with an eye towards content coverage, staying on schedule, and teaching to the test (Beem, 1990; Ediger, 1995). These approaches run counter to the Montessori principle that individual learners should be trusted to know when the right time for learning is and what the learning focus and tasks are to be. The EEE model's curricular recommendations are designed to honor this Montessori principle as well as Popper's (1976) maxim to avoid teaching unwanted answers to unasked questions. The model also draws from the suggestions of a core group of educational theorists who have discussed and researched how Popper's theory of the knowledge building process can be applied to formal learning environments (Bailey, 2000; Burgess, 1977; Perkinson, 1984, 1993; Swann, 1999, 2006, 2007b).

Recommendation #10: Create multi-purpose interdisciplinary learning plans that avoid the fallacy of discipline-specific learning and adapt to students' interests.

Subject areas like mathematics, English, or the sciences, as they are commonly conceived and taught in the standard curriculum, do not regularly provide sufficient flexibility for students to easily seek out and problematize dichotomies across disciplines that they find intriguing and informative (Burgess, 1977; Eisner, 1994). Alternatively, educators must be capable and ready to follow students' lead into areas of new learning that are not necessarily bounded by traditional conceptions of discipline-specific areas of focus. The EEE model recommends that learning be presented as a holistic, seamless experience through which different pedagogical purposes that intermingle different subject areas can be incorporated into one larger scale learning activity. The following provides an elaborated example from which the integrated curricular approach of the EEE model can be further envisioned.

From the day that newborns enter the world, if not before, they are commonly exposed to music and musical-like speech. Babies are sung to, hummed to, played to, and spoken to with highly inflected sing-song-like parent talk. Children quickly discover recorded music from a multitude of sources in their immediate environments, and as they mature, might be taught to sing nursery rhymes, learn how to play a simple tune on an instrument, or dance while listening to a favorite song. Interacting with music in some form would appear to be an experience and an interest that most children bring with them into formal schooling. Curiously, though, this is an experience or interest that is not often drawn upon in an organized way in formal learning environments when it could be

utilized as an attractor and gateway for student explorations of a number of related learning areas.

To learn about music is to also open the door to learning about language, mathematics, science, technology, history, and the creative aesthetics of art forms. Many of the fundamental elements of music closely parallel those of spoken language: stress, intonation, pitch, articulation, and rhythm. These and other related areas such as poetry, rhyme, and metaphors, as well as foreign languages like Italian, are good jumping off points for further linguistic explorations. Reading and writing music reinforces training in left-to-right English conventions and alphabet practice, and it gives students the opportunity to learn a unique, spatially oriented orthographic system. Studying music can initiate more advanced explorations of mathematics beginning with fractions and ratios, as well as discussions of the science of acoustics, physics, and anatomy, including the sense of hearing. Scientific explorations can easily lead toward investigations of the materials and principles of instrument design and construction as well as the development of technology utilized for recording and reproducing sound. Developing an understanding of how musical styles and traditions have changed over the centuries and how they are intertwined and reflective of sociopolitical priorities and popular trends of the era is another avenue for extending the curriculum toward discussions of history. Connections between the history of music and the history of other art forms can also be investigated, including more abstract notions of aesthetic sensibilities like balance and symmetry across all art forms. All of these topic areas can serve as vehicles for extended and advanced interdisciplinary fields of curricular inquiry, and all of them can naturally grow out of, in this case, students' interest in music and a cleverly designed task or set of tasks

that use the topic of music as the common denominator. Well designed learning tasks within the EEE model can effectively integrate multiple purposes, purposes that explicitly instigate a plan for the learning of the moment and implicitly evoke potential future areas of inquiry that are attractive to student explorers.

Recommendation #11: Shift the control and responsibility for determining curricula from adults to students by utilizing student-designed curricula.

The EEE model's recommendation for designing educational curricula that complement the seamless naturalistic learning processes just proposed is for students to become the chief architects and implementers of their own curricula. The approach presented is greatly influenced by Karl Popper's problem solving schema for learning and Maria Montessori's principles of early childhood pedagogy. Additionally, Burgess' (1977) and Swann's (2006, 2007b) investigations of applied Popperian educational contexts in Great Britain have informed a number of aspects of the model's suggestions.

The centerpiece of the EEE model's recommendation is referred to in this dissertation as the Problem Solution Plan (PSP), or the curricular plan for independent study that students are to develop, implement, and assess with teacher guidance and approval over the course of an academic year. The plan emphasizes students' identification of a gap between the state of their skills, competencies, achievements, and interests at a given point in time, in this case the beginning of the first 14-week session of the academic year, and what students anticipate will be their combined abilities and interests at a future period of time, or the conclusion of the third session of the academic year. Similar to Adams and Burgess' (1980) proposal, the tentative solution and hypothesis for resolving this Popperian dichotomy or P1 is a student-designed

curriculum. The PSP serves as this curriculum and details the learnings and required resources students anticipate will help them move from their current developmental space A to their future developmental space B. To be effective, the PSP should be developmentally appropriate for the students' age group and range of abilities. Informed by Swann's (2007b) suggestions, the PSP should also clearly specify in writing the problem to be investigated, the kind of testing to which its hypotheses will be subjected, the amount and type of teacher guidance needed throughout the process, the learning resources likely to be required, and the expected results that signify successful completion of the plan.

The EEE model schedules students' PSPs to be developed over a 3-4 week period at the beginning of the new academic year's first session that is reserved exclusively for academic planning. This planning period will involve extensive collaboration and critical discussion with the student's teacher who serves as the student's learning advisor. Upon approval by the student and teacher, the PSP should then be signed by the student's parents and submitted to a three-person academic committee composed of the school principal and two designated teachers who must unanimously approve each student's PSP. Approval should be granted based primarily on the PSP's feasibility for being completed within the specified time frame utilizing the available resources and on its congruence with the school's general PSP guidelines. To monitor students' learning progress, each student/teacher team will co-assess the student's efforts and adherence to the PSP's stipulations at pre-determined intervals, suggested to be minimally the beginning of each new 14-week session (younger students may likely need more frequent "check-in" discussions). These assessments are intended to be self-reflective formative

descriptions of student progress achieved thus far. Because the learning process is typically an inherently unpredictable one, students should be prepared to identify and eliminate error not only in the actual learning activities themselves but also in the broader development of their learning vis-à-vis their PSP. Toward this end, the PSP's overall trajectory and its individual components are modifiable upon agreement of both the student and the teacher. The EEE model further suggests that learning reviews be conducted, at least in part, with parents in attendance so that their input can be included in the discussions. Parents should also provide their signature of agreement to any approved modifications in the PSP that their child believes should be made.

The final stage for completing the PSP will be a formal self-evaluation by the student with feedback from the teacher. This assessment stage will occur in the final weeks of the third session of the academic year and will document the student's effort and achievement towards fulfilling the PSP's provisions. Details of this culminating assessment stage are presented within next section's recommendations for assessing student's educational progress.

Recommendation #12: Describe student achievement through assessment mechanisms that highlight the process of trial-and-error learning.

Burgess (1977), Perkinson (1984), and others have commented on the consistent similarity throughout centuries of western education of the types of activity that take place within educational institutions that are perceived to constitute human learning. Dating to at least the time of the ancient Greeks, young people have attended lectures and tutorials, read books, written essays, carried out experiments, and completed the equivalent of homework. Teachers are expected to cover and hopefully explain a certain

defined amount of knowledge, and students are then expected to convince their examiners through some type of exam that students have retained, i.e. learned the prescribed set of knowledge. The assumption throughout has been that the actions of teachers teaching and of students receiving the instruction “cause” learning. However, Popper’s philosophy of the nature of knowledge as progressive error elimination through activity that emanates from within learners serves to lay bare the implicit claim that teaching causes learning. Burgess and Perkinson have emphatically argued that, in fact, one activity expressly precludes the other.

For the EEE model, this dichotomy between teaching and learning also strongly suggests that traditional views of how to assess student learning are also mistaken. From this perspective, traditional notions of assigning letter grades to students are overly narrow simplifications of student learning activity, especially if they are derived from quantifying ratios of correct versus incorrect responses given by students on formal tests. Moreover, the current era’s overreliance on high stakes, norm-referenced standardized achievement testing for quantifying the degree to which large groups of students have learned what was taught is woefully, if not perniciously, misguided. For the 14-year-old student referred to throughout this chapter, the EEE model must assure her that formal assessments of her learning process will not penalize her for taking risks with her learning, testing her tentative theories and making errors. The model should encourage her to actively describe her achievements and reflect on how to reduce error in subsequent stages of her learning plans by utilizing alternatives in assessment that hold the greatest potential for documenting her progress within a naturalistic learning environment. It is recommended in the EEE model that assessment provide multi-

dimensional formative descriptions of holistic student learning activity and that progress be conceived within a framework that views learning as a non-linear BVS process of Popperian conjectures and refutations.

The critical discussions and self-reflections described in the previous section that students, teachers, and parents participate in over the course of the EEE model's school year are examples of how a possible holistic alternative in assessment could be structured. The student/teacher discussions over the course of the school year build toward the culminating assessment at the end of the academic year during which the student's PSP Learning Portfolio is presented to the teacher for evaluation and further critical discussion. The portfolio should be an organized collection of student work that highlights through specific referenced samples selected by the student the extent to which the student has tested the hypotheses proposed in the PSP and identified errors that can be or already might have been eliminated. The EEE model proposes that this is best accomplished, at least initially, through a developmentally appropriate written self-assessment essay that examines three specific areas of learning: the changes in the student's understandings that have taken place over time, the ways in which these understandings can help the student, as Bickhard (2002) phrased it, move away from error, and the student's theories and projected strategies for future hypothesis testing of newly noticed P2-type problems. Provided that the student has invested the necessary effort to carry out the specific steps of the PSP that the student initially proposed, then the results of the student's academic investigations and reflections, errors and all, are to be considered acceptable evidence of the student's achievements. Critical feedback, both verbal and written, from the teacher is an important component of the discussions. The

teacher's perspectives, personally as an advanced learner and professionally as an experienced educator, can help guide the student to refine any proposed strategies for future problem formulation and error elimination. Parents and other concerned family members have an important role to play in these end-of-year learning reviews, and their active participation is expected and welcomed in this model.

The twelve recommendations of the EEE model just described represent an integrated approach to education that offers students a formal, theoretically coherent framework for creating knowledge through a system of trial-and-error elimination complementary to naturalistic learning processes. The next chapter discusses in more detail some of the cautions and caveats for the EEE model's potential success should it be implemented. Also to be discussed are directions for future research, the results of which may help to reduce, if not eliminate, any errors in the model's current recommendations.

Chapter 5: Putting the EEE Model into Practice – Cautions, Caveats, and Future Directions

Although most Americans steadfastly maintain that getting a good education guarantees a better society and opens the door to more rewarding careers (Tyack & Cuban, 1995), it has been debated regularly throughout the nation's history what the best set of educational priorities and practices that constitute good schooling should be. As several educational historians described, it is often sociopolitical considerations of power and control that have driven the agendas of educational reform movements in the United States, and these have typically clustered around adult priorities and ideas of how knowledge should be transmitted to children (Cuban, 2003, 2004; Kliebard, 1995, 2002; Perkinson, 1968, 1980, 1984; Tyack & Cuban, 1995). However, it has been asserted in this dissertation that approaches to educational reform should instead be derived from an informed understanding of naturalistic learning so that curricular structures and pedagogical practices start from children and work backwards in support of their intrinsic curiosity and search for regularities in the world around them. Specifically, the purpose of this study was to argue that Karl Popper's philosophy of human knowledge, referred to as an evolutionary epistemology, provides a theoretical framework from which to build educational systems that complement naturalistic human learning. It was further argued that the Montessori system of early childhood education strongly evidences the principles and characteristics of an evolutionary epistemology and that an educational model for reform based on a combined Popperian/Montessorian perspective would best suggest how to reconceptualize learning environments that cohere with and support the patterns and proclivities of human learning.

Cautions and Caveats

The twelve recommendations of the EEE model presented in this dissertation are intended to be a principled guide for providing a foundational structure that, if implemented, should contribute to improving America's educational system. Many of the EEE model's proposals are explicitly grounded in the Montessori tradition, others perhaps less overtly so. Yet, all have been formulated to be consistent with the spirit and approach of Montessori as well as Popper's evolutionary epistemology philosophy. The EEE model should be considered an integrated whole, not just a coincidental collection of twelve maxims, and, in the Popperian tradition, it should be thought of as a bold hypothesis designed to solve a Popperian "P1" of how to optimize the principles and practices of formal learning environments to the fullest extent possible so that children's learning processes may unfold and grow. However, certain obstacles need to be acknowledged and overcome in order to achieve the EEE model's promise for improving teaching and learning. It is to some of the most relevant cautions and caveats that the discussion now turns.

Many of the EEE model's recommendations would likely require extensive changes or adaptations in pedagogy, educational philosophy, systemic practices, and financial commitments. It must first be acknowledged that the forces of institutional and societal inertia, especially where education is concerned, tend to be very strong. To paraphrase a relevant Thai proverb, it takes tremendous effort to push an unwilling elephant up the hill, and significant quantities of effort, and time, are likely to be needed to effect meaningful reform of many ingrained practices. Discussions of educational reform are also invariably accompanied by discussions of cost, and financial

considerations form a significant part of decisions regarding which reforms to implement and which not to, especially in light of the profound disparities in resource availability across localities. However, as necessary as these considerations are to implementing the EEE model, unraveling the complexities, inequities, and politics of funding education in America requires an analysis and set of recommendations that extend beyond the scope of this dissertation. For this reason, the EEE model has been presented in a fiscally blind manner so as to not divert attention from the pedagogical rationale for the model's features, even though it is understood that implementing the model will require very careful attention to financial sensibilities.

Tyack and Cuban (1995) observed that those educational reforms that avoid the pitfalls of the grammar of schooling and grow out of aspects of current practice to become working hybrids of the old and the new are often the types of reforms that tend to have the most staying power and influence. To the extent that this assertion is accurate, then efforts to implement the model's recommendations might gain additional "buy-in" by emphasizing how select parts of the model are similar to or a logical extension of certain practices that already exist in some school systems. Two examples of this were pointed to in the previous chapter's discussion of recommendations related to extending student learning time. Steps referenced as already taken in this direction included an increase in the number of school days per year beyond the 180-day minimum and the doubling of the duration of individual class times through block scheduling.

The EEE model's recommendation to shift the responsibility for determining curricula to students through student-designed independent study plans, called PSPs, is one of the model's more provocative proposals and, perhaps, one of the proposals most

likely to challenge existing ways of conducting education. Yet, in principle, this recommendation is not as foreign to mainstream education as it may at first seem. As more inclusive approaches to mainstream educational practices have been adopted in recent years, students with special needs stemming from an array of learning challenges have been accommodated through Individual Education Plans (IEPs) that stipulate how curricula and assessments will be specifically tailored to support each student's particular range of skills, learning styles, and abilities. Alternatively, students who have the advanced skills and ability to be designated as academically "gifted" may be offered an IEP that is tailored to provide a comparatively more challenging curriculum. Other students who are non-native speakers of English may have an IEP that customizes their learning plan to optimize the level of instructional English used to match their linguistic abilities, thereby giving them scaffolded, or sheltered, instruction and additional learning time for their English fluency to improve. The model for this type of IEP, the Sheltered Instruction Observation Protocol (SIOP), was initially developed for English language learners (ELLs) to make grade-level content comprehensible through techniques that take into account students' second language acquisition process; however, as Echevarria and Vogt (2010) reported, SIOP can provide sheltered instruction in any K-12 content classroom (see also Echevarria, Short, & Powers, 2008; and Echevarria, Vogt, & Short, 2008). These are just a few of the broader examples of mainstream education's steps forward toward the ideal of student-designed curricula as recommended in the EEE model. Pointing to these examples may help to mitigate potential negative perceptions of some of the model's other recommendations that may seem more disruptive to existing practices.

Notwithstanding these and other examples of potential congruence between the EEE model's recommendations and similar practices within some sectors of mainstream education, many more layers to the model will need to be added, developed, and refined over time in order for the model to mature. As additional obstacles are systematically identified and overcome through a process of hypothesis testing and error elimination, the model should become even more robust. Toward this end, future directions for subsequent work can be identified that aim to put to the test, in the fullest Popperian sense of the phrase, the theories and proposals discussed throughout this dissertation.

Future Research Directions

Two research areas, in particular, seem especially relevant and fruitful for investigation and the further elimination of error in the EEE model's design. The first area of research would be directed toward the goal of testing the viability of the complete EEE model by putting it into practice through a pilot study in a cooperative public school environment. The second area of investigation, although separate from the specific goal of the area just described, is an integral component to the success of testing the EEE model's design. This investigation calls for working with a cooperative college of education prior to commencing the curricular study to train teachers in accordance with the EEE model's seventh and eighth recommendations related to teacher training curricula and post-graduate teacher residency. Upon graduation and the completion of a professional residency, teachers who participate in this study would go on to teach in the pilot study of the model's curriculum to determine the effectiveness of the model's suggestions for teacher training programs and teachers' ability to foster student learning processes as explicated throughout the model. Both research areas would likely require

multi-year funding for both longitudinal studies, with funding anticipated to be provided through a grant from a private individual or foundation interested in supporting innovative grass roots educational approaches.

Testing the EEE model's curricular recommendations.

The first proposal is to test the EEE model's recommendations #10-12 regarding developing student-designed curricula and assessments. The intent is for the EEE model to be tested as a whole; therefore, Recommendations #1-5 concerning the structure and organization of the model would be incorporated into the study. Recommendations #6-9 related to revised roles and training for participants in the EEE learning environment should likewise be part of the research, with the training of participating teachers provided as part of the second research area to be discussed below.

This first broad area of research revolves around a pilot study that utilizes a mixture of primarily qualitative measures of student learning to examine the educational achievements of one or two multiple-age groupings of students as defined by the EEE model. Because of the need to adequately test the EEE model in an educational setting that offers a maximum degree of institutional flexibility in supporting alternative principles and practices in curricula, assessment, teacher and parent roles, and structure of the learning organization, it is suggested that a charter school be established expressly for the purpose of conducting this pilot program. It is hypothesized that doing so will significantly diminish the potential for negative "push back" from existing institutional practices and constituents. Further, it is anticipated that this research will highlight the significant degree to which students in this charter school, tentatively named the Karl Popper Academy (KPA), are capable of designing their own curricula and self-assessing

their learning processes while demonstrating to concerned stakeholders system-wide their ability to prepare for rewarding post-high school careers. Data gathered as support for this hypothesis should include pre- and post-study surveys, focus groups, and interviews of students, teachers, parents, and administrators that detail changes in students' self-initiated learning behaviors and attitudes over the course of the study, students' ability to articulate learning problems and follow through with testing self-devised solutions to those problems, students' capability for self-reflection and assessment of their learning process, and perceptions of students' overall effort and achievement in completing the PSP's provisions that they set for themselves. If the students' academic and career achievements are significant enough over time, then the EEE model may positively contribute to subverting the ingrained practices of the prevailing educational system sufficiently enough that the model could be gradually expanded to include other similar charter schools with a wider range of student age groupings.

Testing the EEE model's teacher training recommendations.

The second area of research that investigates the effectiveness of training teachers for new roles within the EEE model is intended to determine the extent to which teachers can be effective facilitators of student learning processes as defined by the EEE model. The cooperative arrangement between a participating college of education and the KPA charter school is based on existing models of Integrated Professional Development Schools (IPDS) in which colleges of education seek to develop a close working relationship with an interested public school. College faculty who are teacher trainers work collaboratively with in-service school teachers to help foster improved teaching and learning practices for students in that school. Additionally, pre-service teachers are often

placed in the cooperating public school for short-term teaching internships (Abdal-Haqq, 1998; see also www.lehigh.edu/education/ipds).

For this research study, graduates of the three-year teaching degree program at the sponsoring college of education would conduct their professional teaching residency at KPA and would have priority for teaching positions at KPA for the remainder of the curricular study described above. Similar to the type and range of data collected for the curricular study, data gathered for this study should include qualitative assessments of teacher effectiveness in promoting learning as conceived within the EEE model. These data would be generated through surveys, focus groups, and interviews with teachers, teacher trainers, parents, and administrators with the goal of assessing teachers' attitudes, beliefs, and practices. Of particular interest would be the degree and type of change over time of teacher's abilities to facilitate students' naturalistic learning processes.

There are numerous additional studies that could grow out of either of these two broader research areas, especially a range of smaller-scale studies that might look at the effectiveness of specific individual recommendations or aspects of recommendations in the EEE model. The hypotheses asserted within the EEE model have been proposed as tentative theories for solving some of formal education's most vexing problems. There are surely errors waiting to be discovered as the model is put to the test, all with the goal, in Bickhard's (2002) words, of moving further away from error on the unpredictable path to formulating newer, ever more interesting problems.

References

- Abdal-Haqq, I. (1998). *Professional development schools: Weighing the evidence*. Thousand Oaks, CA: Corwin Press.
- Adams, E., & Burgess, T. (1980). Conclusion and proposals. In T. Burgess & E. Adams (Eds.), *Outcomes of education* (pp. 163-176). London, England: Macmillan Education.
- Babini, V. (Spring, 2000). Science, feminism, and education: The early works of Maria Montessori. *History Workshop Journal*, 49, 44-67. Translation by Sarah Morgan and Daniel Pick.
- Bacharach, S. (1990). Education reform: Making sure of it all. In S. Bacharach (Ed.) *Education reform: Making sense of it all* (pp. 1-6). Boston: Allyn & Bacon.
- Bailey, R. (2000). *Education in the open society: Karl Popper and schooling*. Hampshire, England: Ashgate.
- Baird, F., & Kaufmann, W. (2003). *From Plato to Derrida* (4th ed.). Upper Saddle River, NJ: Prentice Hall.
- Beem, R. (October 1, 1990). Recent scope-and-sequence models. *Councilor*, 50, 17-30.
- Berkson, W., & Wettersten, J. (1984). *Learning from error: Karl Popper's psychology of learning*. LaSalle, IL: Open Court.
- Bickhard, M. (2001). Error dynamics: The dynamic emergence of error avoidance and error vicariants. *Journal of Experimental and Theoretical Artificial Intelligence*, 13, 199-209.
- Bickhard, M. (2002). Critical principles: On the negative side of rationality. *New Ideas in Psychology*, 20, 1-34.

- Bickhard, M., & Campbell, D. (2003). Variations in variation and selection: The ubiquity of the variation-and-selective-retention ratchet in emergent organizational complexity. *Foundations of Science, 8*, 215-282.
- Bickhard, M., & Campbell, R. (1996). Topologies of learning and development. *New Ideas in Psychology, 14*(2), 111-156.
- Borman, G., Goetz, M., & Dowling, M. (2009). Halting the summer achievement slide: A randomized field trial of the KindergARTen summer camp. *Journal of Education for Students Placed at Risk, 14*, 133-147.
- Buckenmeyer, R. (Winter, 1999). Maria Montessori: A learner taught by children. *The NAMTA Journal, 24*(1), 244-253.
- Burgess, T. (1977). *Education after school*. London, England: Victor Gollanz.
- Campbell, D. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review, 67*, 380-400.
- Campbell, D. (1974). Evolutionary epistemology. In P. Schilpp (Ed.), *The philosophy of Karl Popper, Book 1* (pp. 413-463). LaSalle, IL: Open Court.
- Campbell, D. (1997). From evolutionary epistemology via selection theory to a sociology of scientific validity. [Posthumously edited by C. Heyes & B. Frankel] *Evolution and Cognition, 3*(1), 5-38.
- Celano, D., & Neuman, S. (December, 2008). When schools close, the knowledge gap grows. *Phi Delta Kappan, 90*, 256-262.
- Chaney, B., & Lewis, L. (2007). *Public school principals report on their facilities: Fall 2005* (NCES 2007-007). U. S. Department of Education. Washington, DC: National Center for Education Statistics.

- Chattin-McNichols, J. (1992). *The Montessori controversy*. Albany, NY: Delmar.
- Cremin, L. (1977). *Traditions of American education*. New York: Basic Books.
- Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: Harper & Row.
- Cuban, L. (1990). Why do some reforms persist? In S. Bacharach (Ed.) *Education reform: Making sense of it all* (pp. 135-140). Boston: Allyn & Bacon.
- Cuban, L. (1993). *How teachers taught: Constancy and change in American classrooms, 1890-1990* (2nd ed.). New York: Teachers College Press.
- Cuban, L. (2003). *Why is it so hard to get good schools?* New York: Teachers College Press.
- Cuban, L. (2004). *The blackboard and the bottom line: Why schools can't be businesses*. Cambridge, MA: Harvard University Press.
- Deci, E., & Flaste, R. (1995). *Why we do what we do: The dynamics of personal autonomy*. New York: Putnam.
- Deci, E., & Ryan, R. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.
- Doll, W. (2005). The culture of method. In W. Doll, J. Fleener, D. Trueit, & J. Julien (Eds.), *Chaos, complexity, curriculum, and culture* (pp. 21-75). New York: Peter Lang.
- Echevarria, J., Short, D., & Powers, K. (2008). Making content comprehensible for non-native speakers of English: The SIOP model. *The International Journal of Learning*, 14(11), 41-49.

- Echevarria, J., & Vogt, M. (2010). Using the SIOP to improve literacy for English learners. *NERA Journal*, 46(1), 8-15.
- Echevarria, J., Vogt, M., & Short, D. (2008). *Making content comprehensible for English learners: The SIOP model* (3rd ed.). Boston, MA: Allyn & Bacon.
- Ediger, M. (Fall, 1995). Sequence and scope in the curriculum. *Education*, 116(1), 159-161.
- Edmonds, D., & Eidinow, J. (2001). *Wittgenstein's poker: The story of a ten-minute argument between two great philosophers*. London: Faber & Faber.
- Eisner, E. (1994). *Cognition and curriculum reconsidered* (2nd ed.). New York: Teachers College Press.
- Foschi, R. (Summer, 2008). Science and culture around the Montessori's first "Children's Houses" in Rome (1907-1915). *Journal of the History of the Behavioral Sciences*, 44(3), 238-257.
- Gandara, P., & Fish, J. (Spring, 1994). Year-round schooling as an avenue to major structural reform. *Educational Evaluation and Policy Analysis*, 16(1), 67-85.
- Gerstner, L., Semerad, R., & Doyle, D. (1994). *Reinventing education: Entrepreneurship in America's public schools*. New York: Plume.
- Goodlad, J. (1984). *A place called school*. New York: McGraw-Hill.
- Heinich, R. (1991). Restructuring, technology, and instructional productivity. In G. Anglin (Ed.) *Instructional technology: Past, present, and future* (pp. 236-243). Englewood, CO: Libraries Unlimited.

- Hill, P., & Roza, M. (2010, July). *Curing Baumol's disease: In search of productivity gains in K-12 schooling*. Seattle: Center on Reinventing Public Education.
Retrieved from http://www.crpe.org/cs/crpe/view/csr_pubs/343
- Hume, D. (1748/2003). An enquiry concerning human understanding. In F. Baird & W. Kaufmann (Eds.), *From Plato to Derrida* (4th ed., pp. 714-790). Upper Saddle River, NJ: Prentice Hall.
- Itard, J. (1932). *The wild boy of Aveyron*. New York: The Century Company. Translated from the original French by George & Muriel Humphrey.
- Kliebard, H. (1992). *Forging the American curriculum*. New York: Routledge.
- Kliebard, H. (1995). *The struggle for the American curriculum, 1893-1958* (2nd ed.). New York: Routledge.
- Kliebard, H. (2002). *Changing course: American curriculum reform in the 20th century*. New York: Teachers College Press.
- Kohn, A. (1993). *Punished by rewards*. Boston: Houghton Mifflin.
- Kramer, R. (1988). *Maria Montessori: A biography*. Cambridge, MA: Perseus Publishing.
- Ladyman, J. (2002). *Understanding philosophy of science*. New York: Routledge.
- Lakatos, I. (1974). Popper on demarcation and induction. In P. Schilpp (Ed.), *The philosophy of Karl Popper, Book 1* (pp. 241-273). LaSalle, IL: Open Court.
- Larsen-Freeman, D., & Cameron, L. (2008). *Complex systems and applied linguistics*. New York: Oxford University Press.

- Lawrence, W., & McPherson, D. (September, 2000). A comparative study of block scheduling and traditional scheduling on academic achievement. *Journal of Instructional Psychology*, 27(3), 178-182.
- Lillard, A. (2007). *Montessori: The science behind the genius*. New York: Oxford University Press.
- Lillard, A. (2011, Fall). What belongs in a Montessori primary classroom? *Montessori Life*, 23(3), 18-32.
- Lillard, P. (1980). *Montessori in the classroom*. New York: Shocken Books.
- Lipton, P. (1998). Induction. In M. Curd & J. Cover (Eds.), *Philosophy of science: The central issues* (pp. 412-425). New York: W. W. Norton.
- Locke, J. (1690/2003). An essay concerning human understanding. In F. Baird & W. Kaufmann (Eds.), *From Plato to Derrida, 4th ed.* (pp. 554-608). Upper Saddle River, NJ: Prentice Hall.
- Losee, J. (2001). *A historical introduction to the philosophy of science* (4th ed.). New York: Oxford.
- Magee, B. (1973). *Karl Popper*. New York: Viking Press.
- Miller, D. (1983). *A pocket Popper*. Great Britain: Fontana.
- Montessori, M. (1912). *The Montessori method*. New York: Frederick Stokes.
- Montessori, M. (1914/1965). *Dr. Montessori's own handbook*. New York: Shocken Books.
- Montessori, M. (1915/1997). *The California lectures of Maria Montessori, 1915: Collected speeches & writings*. R. Buckenmeyer (Ed.). Oxford, England: Clío Press.

- Montessori, M. (1917/1965). *Spontaneous activity in education*. New York: Schocken Books.
- Montessori, M. (1967/1984). *The absorbent mind*. New York: Dell Publishing Company.
- National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Washington, DC: U.S. Government Printing Office.
- Ormerod, R. (2009). The history and ideas of critical rationalism: The philosophy of Karl Popper and its implications for OR. *Journal of the Operational Research Society*, 60, 441-460.
- Passow, A. H. (1990). How it happened, wave by wave. In S. Bacharach (Ed.) *Education reform: Making sense of it all* (pp. 10-19). Boston: Allyn & Bacon.
- Perelman, L. (1992). *School's out: A radical new formula for the revitalization of America's educational system*. New York: Avon.
- Perkinson, H. (1968). *The imperfect panacea: American faith in education, 1865-1965*. New York: Random House.
- Perkinson, H. (1980). Education and the new pluralism. In R. Swartz, H. Perkinson, & S. Edgerton (Eds.) *Knowledge and Fallibilism: Essays on improving education* (pp. 103-117). New York: New York University Press.
- Perkinson, H. (1984). *Learning from our mistakes: A reinterpretation of twentieth-century educational theory*. Westport, CT: Greenwood Press.
- Perkinson, H. (1993). *Teachers without goals/Students without purposes*. New York: McGraw-Hill.

- Plekhanov, A. (1989). The pedagogical theory and practice of Maria Montessori.
Doshkol'noe vospitanie, 10, 83-96. Russia: State Committee for Education.
Translated from the original Russian.
- Popper, K. (1934/1959). *The logic of scientific discovery*. London: Hutchinson & Co.
- Popper, K. (1944). *The poverty of historicism*. London: Routledge.
- Popper, K. (1945). *The open society and its enemies (Volumes I & II)*. London:
Routledge.
- Popper, K. (1960/1983). Knowledge without authority. In D. Miller (Ed.) *A pocket
Popper* (pp. 46-57). Great Britain, Fontana.
- Popper, K. (1963). *Conjectures and refutations: The growth of scientific knowledge*.
London: Routledge.
- Popper, K. (1967/1983). Knowledge: Subjective versus objective. In D. Miller (Ed.) *A
pocket Popper* (pp. 58-77). Great Britain, Fontana.
- Popper, K. (1973/1983). Evolutionary epistemology. In D. Miller (Ed.) *A pocket Popper*
(pp. 78-86). Great Britain, Fontana.
- Popper, K. (1976). *Unended quest: An intellectual autobiography*. LaSalle, Illinois: Open
Court.
- Popper, K. (1977/1983). Natural selection and its scientific status. In D. Miller (Ed.) *A
pocket Popper* (pp. 239-246). Great Britain, Fontana.
- Popper, K. (1994). *The myth of the framework*. M. A. Notturmo (Ed.). New York:
Routledge.
- Popper, K. (1999). *All life is problem solving* (Patrick Camiller, Trans.). London:
Routledge.

- Povell, P. (2010). *Montessori comes to America*. Lanham, MD: United Press of America.
- Provasnik, S., Gonzales, P., and Miller, D. (2009). *U.S. performance across international assessments of student achievement: Special supplement to the condition of education 2009* (NCES 2009-083). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.
- Putnam, H. (1974). The “corroboration of theories.” In P. Schilpp (Ed.), *The philosophy of Karl Popper, Book 1* (pp. 221-240). LaSalle, IL: Open Court.
- Rambusch, N. (1962). *Learning how to learn: An American approach to Montessori*. Baltimore: Helicon Press.
- Ripley, A. (2010, September 20). A call to action for public schools. *Time*, 176(12), 32-42.
- Saettler, P. (1990). *The evolution of American educational technology*. Englewood, Colorado: Libraries Unlimited.
- St. Gerard, V. (April, 2007). Year-round schools look better all the time. *The Education Digest*, 72(8), 56-58.
- Seguin, E. (1866/1907). *Idiocy: And its treatment by the physiological method*. New York: Teachers College, Columbia University.
- Shorto, R. (2010, February 14). Founding father? *The New York Times Magazine*, 32-39, 46-47.
- Shute, N. (September, 2002). Madam Montessori. *Smithsonian*. Retrieved from <http://www.smithsonianmag.com/people-places/montessori.html>

- Standing, E. M. (1957). *Maria Montessori: Her life and her work*. New York: Mentor-Omega Books.
- Swann, J. (1999). The logic-of-learning approach to teaching: A testable theory. In J. Swann & J. Pratt (Eds.), *Improving education* (pp. 109-120). London, England: Cassell.
- Swann, J. (2003). A Popperian approach to research on learning and method. In J. Swann & J. Pratt (Eds.), *Educational research in practice* (pp. 11-34). London, England: Continuum.
- Swann, J. (2006). How to avoid giving unwanted answers to unasked questions. In I. Jarvie, K. Milford, & D. Miller (Eds.) *Karl Popper: A centenary assessment, Volume 3* (pp. 261-271). Burlington, VT: Ashgate.
- Swann, J. (2007a). The myth of learning by instruction from without. *Higher Education Review*, 40(1), 37-51.
- Swann, J. (2007b). Teaching for a better world: The why and how of student-initiated curricula. In D. Aspin & J. Chapman (Eds.) *Values education and lifelong learning* (pp. 279-294). England: Springer.
- Swann, J. (2009). Learning: An evolutionary analysis. *Educational Philosophy and Theory*, 41, 256-269.
- Swann, J. & Pratt, J. (1999). *Improving education*. London, England: Cassell.
- Swartz, R. (1980). Towards a fallibilistic perspective. In R. Swartz, H. Perkinson, & S. Edgerton (Eds.) *Knowledge and fallibilism: Essays on improving education* (pp. IX-LV). New York: New York University Press.

- Swartz, R. (Winter, 1985). Dewey and Popper on learning from induction. *Interchange*, 16(4), 29-51.
- Thornton, S. (2009, February 9). Karl Popper. *Stanford Encyclopedia of Philosophy*. Retrieved from <http://plato.stanford.edu/entries/popper>
- Tyack, D., & Cuban, L. (1995). *Tinkering toward utopia: A century of public school reform*. Cambridge, MA: Harvard University Press.
- Veal, W. (2000). Teaching and student achievement in science: A comparison of three different schedule types. *Journal of Science Teacher Education*, 11, 251-275.
- von Bertalanffy, L. (August, 1950). An outline of general system theory. *The British Journal for the Philosophy of Science*, 1(2), 134-165.
- Whitescarver, K., & Cossentino, J. (December, 2008). Montessori and the mainstream: A century of reform on the margins. *Teachers College Record*, 110, 2571-2600.

Author Biography

Timothy W. Cauller, Director of the StepUp Intensive English Program and Associate Director of English as a Second Language (ESL) at Lehigh University, has over 20 years of professional experience as an English language teacher and administrator. Tim's international experience includes teaching English as a Foreign Language (EFL) for the Ministry of Foreign Affairs at the Foreign Service Training Institute in Tokyo, Japan and advising students on college selection and admissions for the Yokohama YMCA's Study Abroad program. In Japan, Tim taught TOEFL, GRE, and GMAT preparation, English conversation, and presented on American cultural and musical traditions. Since joining Lehigh University in 1998, he has taught courses in academic and technical writing, academic speaking and listening, advanced presentation skills, and American pragmatics to international graduate and undergraduate students from over 50 countries. He has also taught courses in second language acquisition and the principles and practices of ESL pedagogy to pre-service teachers from the College of Education and the College of Arts and Sciences.

Prior to Tim's career in academe, Tim pursued a career in the music industry, working as a performing musician, saxophone instructor, and sales consultant in the home audio & video business. He has also worked in higher education as a college admissions counselor and has recruited students throughout Japan and the United States for Berklee College of Music. He has traveled extensively throughout much of Asia, parts of Europe and the Caribbean, and has a working knowledge of Japanese, German, and conversational Thai.

Tim holds a Master of Arts (MA) in TESOL (Teaching English to Speakers of Other Languages) and a certificate in Language Program Administration from the Monterey Institute of International Studies in Monterey, California. He holds a Bachelor of Music (BM) in Performance/Professional Music from Berklee College of Music in Boston, Massachusetts. He is completing his doctoral program in Curriculum & Instruction in the College of Education at Lehigh University in Bethlehem, Pennsylvania. His research focuses on learning theory and cognition, drawing heavily on philosopher Karl Popper's evolutionary epistemology and Italian educator Dr. Maria Montessori's Montessori system of early childhood education. Tim's doctoral program advisor is Dr. MJ Bishop, Associate Professor of Education and Human Services, in the Teaching, Learning, & Technology program.