A Holy Curiosity: Transformative Self-Directed Learning to Breakthrough New Knowledge in the Case of Einstein

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A HOLY CURIOSITY: TRANSFORMATIVE SELF-DIRECTED LEARNING TO BREAKTHROUGH NEW KNOWLEDGE IN THE CASE OF EINSTEIN

by

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Abstract of a Dissertation
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ABSTRACT

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The case of Einstein’s discovery of the relativity theory, explored with grounded theory methodology, illustrates a type of self-directed learning characterized by personal and non-personal, or technical, transformative learning, the result of which is iconic original, breakthrough learning. This dissertation explores three aspects of adult learning which are novel in adult education.

First, this study of breakthrough process, for which there is only one apparent precedent in adult education, considers how an individual goes about a self-directed learning project that revolutionizes a field. In this regard, the concept of original learning, as opposed to transmitted learning, presents itself as a valid element of adult learning and adult education. Next, the results argue for an expanded view of transformative learning: that it is not limited to adulthood, or to personal or socio-cultural domains, or to absolute designations of either completed transformative or non-transformative learning.

Finally, considering the patterns in Einstein’s breakthrough journey in light of other models of breakthrough yields a broadly common process of breakthrough via challenge formation, navigating new territory, persevering through a long ordeal, and finally an actualization process of validation and integration. This common pattern can be found in the other model of self-directed breakthrough learning (Cavaliere’s example of the Wright brothers’ invention of flight); in Mezirow’s model of personal or socio-
cultural transformative learning; in Campbell’s archetype of the hero’s journey in literature, film, and other forms of myth and story (elaborating Aristotle’s three-part structure for plot dynamics), and also in a neurobiological model of exceptional creativity based on classic creativity theory and contemporary scientific research.

This grounded theory of independent breakthrough learning integrates these concepts. The result is a model of a meaningful question (passionate curiosity in a personally meaningful context) meeting transformative attention (critical reflection and a multi-dimensional process of deep interaction with the question), resulting in a breakthrough learning posture that can yield results on a continuum from creatively discovered answers in the existing base of human knowledge, to incremental contributions to that knowledge base, to profoundly transformative changes in perspective and capability in a field of human endeavor.
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DEDICATION

This dissertation is dedicated to Larry, with love and gratitude.
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Special thanks and recognition go to Dr. Lorraine Cavaliere for inspiring the topic, methodology, and this writer; for blazing a brilliant trail and never giving up, and for being a comrade and friend in this unusual work. A grateful embrace is offered to Dr. Lin Harper for her presence and approach as an adult educator who walks the talk, and for stimulating and giving free reign to flights of curiosity and exploration in all of her courses, and especially the Adult Learning course that sparked the work represented in this dissertation. Sincere gratitude is also extended to Dr. Michael Wertheimer of the University of Colorado for providing generous access to the Einstein file from the records of his father, the late Dr. Max Wertheimer.
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CHAPTER I
EINSTEIN: ICONIC BREAKTHROUGH LEARNER

It is nothing short of a miracle that the modern methods of instruction have not yet entirely strangled the holy curiosity of inquiry; for this delicate little plant, aside from stimulation, stands mainly in need of freedom.

—Albert Einstein

Einstein’s Relativity

This study in knowledge-transformative self-directed learning examined the learning processes and experiences of a single, independent breakthrough learner, Albert Einstein. Though he is globally recognized and celebrated half a century after his death, Einstein’s contributions are little understood outside their technical fields. For that reason, a brief review of the significance of his work in relativity is a useful starting point.

On an ordinary afternoon in Munich in 1889, a ten-year-old boy sat down to a dinner with his parents, his younger sister, and an intriguing new dinner guest. The boy was Albert Einstein, and the guest, who would appear for weekly visits over the next five years, was a young medical student named Max Talmey. Talmey would become an intellectual and professional mentor at a tumultuous time in the boy’s life.

Even at ten, young Einstein was struggling with issues of purpose, meaning, and futility, seeing early the vanity of human material strivings and superficial direction in life. He had turned to religion as a way out of this futility, practicing in a Jewish household that was proud to be free of what his father called religious superstitions (Jammer, 1999). But Talmey would introduce new ideas and ways of thinking which
provided direction to Einstein’s intense desire for a meaningful, comprehensible life and a connection to greatness beyond his material existence.

The young intellectual at his dinner table treated Einstein with the respect and attention of a peer, and introduced him to a range of philosophical and scientific thought that challenged old assumptions, including his religious beliefs. He also helped Einstein make sense of nagging questions about the forces behind the workings of the universe. Einstein delighted in the popular science books that Talmey helped him obtain. He devoured them with careful study. Over time, influenced by his studies, by his young mentor, and surely by the science-appreciating culture of the academic and industrial powerhouse that was late nineteenth-century Germany, Einstein developed a sense of himself as a young inquirer who, he believed, would soon join the ranks of the scientists whose works were presented in these treasured volumes of natural science.

While Einstein was soaking his adolescent mind in scientific thought and study, Croatian Nicola Tesla was competing in the United States with Thomas Edison over inventions in lighting and electricity distribution, Rudolf Diesel was patenting an internal combustion engine in Augsburg Germany, Wilhelm Rontgen was nearby in Munich learning how to produce the X-ray wavelength radiation that would earn him the first Nobel prize in Physics (in 1901), and the Wright brothers were introducing their own brand of bicycle and devouring the early literature on aerodynamics in Dayton, Ohio. In the same spirit of these doggedly and passionately executed learning projects, and at the same time, the young Einstein was developing a fascination with light, its form and speed, and the relative perspectives one might gain from observing it directly, behind the light beam, or alongside it. His kindly nurtured scientific bent, that powerful but
transitory fixation on religion, and an enduring desire to understand a non-personal but creator God, combined to support this spark of wonder and send Einstein on a lifelong journey of independent, self-directed learning (Gregory, 2000; Highfield & Carter, 1993; Jammer, 1999; Stachel, 2002a; Wertheimer 1944/1982).

The theories of relativity are the iconic achievement of this most popular scientist in history. The first theory, famously developed in 1905 when Einstein was a twenty-six year old clerk at the Swiss Patent Office near the clock tower in Bern, is the special theory of relativity. Einstein achieved this breakthrough as an independent learner seeking to understand those puzzles of nature which had compelled him from childhood. He was a college-educated young man but largely an autodidact, not yet in possession of a doctorate. Spurned by all of his academic contacts for any type of teaching or laboratory work, he had never worked a day as a scientist. He struggled to support a young family in a city his wife hated, but reached out to participate in learning-circle conversations and relationships whenever and however he could. This is the young adult learner who studied, thought, calculated, and wrote in his spare moments, at long last emerging from apparent failure to begin one of the most famous and transformative independent-learning careers in history (Clark, 1971; Denis, 1996; Einstein 1905r/1998d; Isaacson, 2007; Stachel, 2006).

This first theory of relativity that Einstein devised states that when we observe something in uniform motion relative to us, time passes differently—more slowly—for the thing in motion than it does for us. The special theory soon gave birth to the famous equation, \( E=mc^2 \), from which we understand that matter and energy are equivalent, and that neither can be completely destroyed, only transformed. The special theory also
informs us that the speed of light is a constant in the universe, not changing even when
the source of light is in motion. Finally, the special theory re-conceptualized space and
time as an integrated unit, often referred to as a fabric of space-time (Bachelard, 1970;

These concepts were revolutionary to the point of incredulity at the time,
especially coming from a largely unknown, solitary, and unaffiliated scientific thinker.
Still, for all of the revolutionary implications, the special theory was true only for objects
in relative motion. Einstein still had work to do to understand the dynamics of light,
mass, and energy generally. Ten years later, having worked on the general relativity
problem first from his patent office in Bern where he had a grand eureka moment toward
the general theory, and from his university office in Zurich, then from a university office
in Prague, then back in Zurich (where he finally got to teach at his alma mater and where
he received intensive math tutoring from an old college friend), then at last completing
the relativity theory from a university office in World War I-focused Berlin, he finally
had the general theory of relativity in hand. What he really had was a completely new
understanding of gravity. Einstein showed us that mass and energy act upon space-time,
causing it to curve much as a person lying in a hammock causes the fabric to curve, or
sag. This curvature of space-time is the effect we know as gravity. The numerous further
implications of the general theory of relativity shape physics, cosmology, and many other
related sciences and technologies today (Anderson, 2005; Einstein, 1928/2002; Hawking,

For example, our global positioning systems must be engineered to factor in the
effects of both special and general relativity. GPS technology guides airplanes and other
GPS-equipped devices by sending signals from 24 networked satellites, each containing an extremely accurate atomic clock which signals the GPS device. The device orients itself using the time and position signals from multiple satellites, which are in motion relative to the earth. This could be problematic, since, true to special relativity, the satellite clocks run more slowly in our perception, relative to our observation of earth-bound clocks. Clocks on these satellites and clocks on earth would naturally become further out of sync each day.

The dilemma is compounded by general relativity, which accurately predicts that time will go by more slowly in the high orbits of the GPS satellites than it will on earth. This effect is caused by the reduction of space-time curvature that far from the massive earth. In other words, space-time is more curved in the presence of greater mass. Heavy things increase curvature (and therefore gravity) in space-time just as they do in hammocks. Because of space-time integration, time goes by more quickly in the presence of greater mass. To compensate for these effects of relativity, engineers adjust the clocks on the GPS satellites before launching them, and also build in computers that make other compensations while in orbit. In this way, and so many others, the world continues to move to the still-unfolding beat of (arguably) the world’s favorite self-directed learner (Pogge, 2009; Bernstein, 2006; Epstein, 1997; Goldsmith, 2006; Hey & Walters, 1997; Magueijo, 2003/2006, 2005; Robinson, 2005).

Retracing Einstein’s Experience

The purpose of this research was to understand Einstein’s processes and experiences as he moved toward his relativity breakthroughs. Science historians have made progress in reconstructing Einstein’s relativity theories from the point of view of
scientific concepts as building blocks: What did he know, when did he know it, and how did these precepts and data points come together in the revolutionary force of an entirely new way of looking at the universe and how we experience it?

While Einstein’s collection and reconstruction of these scientific concepts over the decades of his learning project is an important input to this research, it is not the focus. Instead, the issue is finding out what learning behaviors, cognitive processes, motivators, and strategies for overcoming obstacles Einstein brought to the work. Here, the scope is turned on the learner, holistically, rather than on his chosen subject. Just as Cavaliere, whose 1988 adult education dissertation at Rutgers used the learning processes of the Wright brothers to contribute a model of self-directed independent learning to our understanding of creative adult learning strategies, and did not add to the technical history of aerodynamic construction, this study makes no attempt to re-envision the historic trajectory of theoretical physics.

Coming to a coherent understanding of the learning processes of a highly independent historical figure in an esoteric field is a formidable undertaking, but as with Cavaliere’s work with the Wright brothers’ case, the tools of grounded theory methodology were useful in parsing out contexts and patterns from the voluminous collected documents related to Einstein’s life and work, so that a conceptual understanding of the research picture eventually formed into the theory of breakthrough learning presented here. As a result, a view of the learning experiences of another highly successful independent original learner is accessible to those concerned with adult learners, or, for that matter, exceptional creative learners of any age. At the least, this research supplants the typically murky understanding of how his work progressed, as
illustrated in this humorous “proposal by Einstein” for his breakthrough learning project:

“This proposal is for the study of the nature of space and time. Method: Conduct thought experiments in armchair, supported by abstract mathematics. Duration: 1 lifetime” (Loehle, 1990, p. 125). His learning journey was so much more than that, and so much more relevant to learners, educators, and facilitators of original learning today.

The model of breakthrough learning (original and paradigm-transforming contribution to a knowledge field) presented here, based on the Einstein data, integrates three significant findings relative to adult education theory. These findings are a) the relevance of original learning (contribution to a knowledge domain, as opposed to acquisition of extant knowledge) to a full understanding of learning as a construct; b) a broader conceptualization of transformative learning (perspective transformation and integration) and its contexts, and c) an informative meta-view of patterns of breakthrough learning taken from the Einstein and Wright brothers cases, and from neurobiological creativity theory, models of development in mythology and drama, and classic views of self-direction and transformative learning in adult education theory. At a high level view, the model describes passionate questions given transformative attention (critical reflection combined with a dimensional process of exploration and problem-solving), resulting in an array of creative answers, learning contributions, and revolutionary paradigm transformations. (In Appendix A the reader will find a glossary of terms relevant to the model presented here, to adult education theory in general, to the grounded theory research methodology applied in this study, and to Einstein’s work in developing his theories of relativity.)
Breakthrough Learning in Context

The significant theoretical lineage of this model is found in the literature of transformative and self-directed learning, creativity and the breakthrough process, and genius and exceptional performance. Further clarification and illustration come from the breakthrough journey as envisioned in the ancient art of storytelling, and in the futuristically-oriented revelations of contemporary neuroscience.

Breakthrough learning, a form of original learning, is not well understood in any field, though research is ongoing. Breakthrough learning is particularly under-investigated in adult education. Nevertheless, in the age of technological wonders and scientific salvation, we take for granted that breakthroughs will occur as needed. Still, it is necessary and possible to support the work of future curious and creative thinkers.

The single breakthrough learning focus of adult education, transformative learning, addresses personal paradigm transformation, usually in a psycho-social, spiritual, or social transformation context. Mezirow’s (1991, 1997, 1998, 2009) non-linear and recursive stages of personal transformational learning include the disorienting dilemma, examination of the present state, critical assessment of assumptions, exploration of options, confidence development, initiation of new actions and acquisition of new knowledge and skills, practice from a new perspective, and acceptance of feedback. The key principles and processes of the Mezirow model, if not each of his ten steps, can now be seen, via the Einstein experience and comparison to other models of breakthrough, to have analogues in the framework of objective breakthroughs, or transformations, which are just as surely paradigm transformations, often richly transformative for masses of individuals (objectively and sometimes also personally), and
for society. These transformative breakthroughs result in significant new knowledge creation, resulting in social (e.g., Marx and Ghandi) or scientific-technological (e.g., Gutenberg and Einstein) paradigm shifts. The scope of these impacts is surely worthy of consideration as a learning process.

Mezirow’s introduction of personal transformation theory to the field of education was wrapped in the communicative rationality and discourse ethics of sociologist Jurgen Habermas (Mezirow, 1991). Habermas offered a substitute for the standard philosophy of rationality, wherein human reason is considered a valid source of knowledge or justification. He proposed that an interactive form of rationality, with people challenging and validating individual views in comparison with the reasoning of others, was superior in that it could be expected to advance social justice, or emancipatory, issues in the human condition (Habermas, 1984). This notion is reflected in Mezirow’s emphasis on a learner coming to understand that problems are shared by others, on talking with others about the learning issue as a key learning process, and on validating any changes in perspective by comparing personal perspective shifts with group wisdom.

Just as Mezirow sought to formalize an historically important theme in adult education—social justice—through his conceptualization of a process of breakthrough, the model presented here means to formalize and introduce a theme of original knowledge creation and breakthrough learning into adult education as a result of coming to an understanding of Einstein’s learning work. The self-directed learner has found a home in adult education, as has the learner undergoing personal transformation, and also the learner concerned with experience and treatment of humans in a full spectrum of
difference. This model invites another learner under the adult education umbrella: the creative seeker of original knowledge or of expanded human capability.

Another thorny aspect of this research puzzle was the concept and historical context of genius, or exceptionally high degrees of innate talent and ability, and the association with exceptional learning, creativity, and performance. A core difficulty in the genius context is the common practice of using genius as an unenlightening circular justification for exceptionally creative results. (Breakthrough, discovery, and invention are exceptional, a fact which is explained by exceptional ability, which is then rationalized as an exceptional act of nature; thus the exceptional is accounted for by its own exceptionality.) Research in other fields casts new light on old assumptions about this relationship. Adult education has a similar opportunity to look more carefully at this component of learning success. While childhood education theory takes into some account the phenomena of giftedness in students, adult education scarcely addresses this component of learning, despite the growing interest exhibited in the fields of psychology, performance studies, neurobiology, and industry.

The Breakthrough Learner and Adult Education

Of all of the central elements of this research problem, that of the learner as a distinct feature of breakthrough learning is the best understood in adult education. An important foundation of inquiry and discussion exists in the areas of self-directed and independent learning. There is an uncanny persistence of this variable in any list of transformative discovery and invention. Yet, despite the groundwork already formed in the study of the adult learner, not a lot has been known, or indeed asked, about the creative learner who takes on original, new knowledge learning projects, much less the
learner who succeeds brilliantly. How are these learners motivated? Where do their
questions come from? How do they negotiate the unknown territory of the original
learning effort? How do they overcome obstacles? What causes them to persevere? These
questions have been asked about self-directed learning in general, but there has not been
much, if any, distinction between original learning and established learning, or between
ordinary learning projects and the impactful project with transformative potential or
outcome. That gap must be addressed in order to understand the breakthrough
phenomenon as a whole.

Adult learning research is generally geared to understanding the acquisition of
established knowledge. For the most recent edition of the *Handbook of Adult and
Continuing Education* (Kasworm, Rose, & Ross-Gordon, 2010), Hansman & Mott (2010)
recap key viewpoints on adult learning activities without coming any closer to the idea
of original learning than standard transformative or emancipatory learning concepts.
Likewise, Brookfield’s (2010) theoretical frameworks for adult education revolve around
emancipatory objectives for adult education. Welton’s (2010) assessment of the adult
education histories concerns itself primarily with socio-political and epistemological
paradigms. These sources reflect the increasing “centrality of social justice” in the
authoritative stances of adult education (Kasworm, Rose, & Ross-Gordon, p. 338), and
the continuing irrelevance of original learning to the field.

Contemporary definitions of adult education, it should be noted, do not exclude
original learning from the purview of adult education. Kasworm, Rose, and Ross-Gordon
(2010) adopt Merriam and Brockett’s (2007) definition of adult and continuing
education: “[adult education consists of] ‘activities intentionally designed for the purpose
of bringing about learning among those whose age, social roles, or self-perception, define them as adults” (as cited in Kasworm, Rose, & Ross-Gordon, 2010, p. 1). This research project aims to help expand the presumed borders of “bringing about learning.”

Bennett & Bell (2010), writing in the Handbook about the knowledge society, do acknowledge that “knowledge creation and sharing are necessary in the global knowledge society” (p. 414). They describe knowledge creation in terms of research, reformulations of extant knowledge, and as a result of “the dynamic interplay between brain and device” (p. 414). They say that “new knowledge is created, for example, when one plays with numbers in an electronic savings calculator and preserves different scenarios to revisit later. This allows an adult to build knowledge through experimentation” (p. 414).

For the most part, Bennett and Bell’s focus, appropriately reflecting the focus of the field, is on education’s role in facilitating competent and critical knowledge consumption in the face of new knowledge created elsewhere, mostly as a result of “significant global growth of knowledge through information exchange” (p. 412). They do suggest that because of the potential for confused interpretations of meaning, stemming from the increasing overlap of content and technological wizardry in the presentation of research findings, “new possibilities [are opened up] for understanding how research is conducted and how new knowledge is created by researchers. The knowledge society will demand greater understanding of knowledge creation through all avenues of research and practice” (p. 419). Not unexpectedly, there is no mention of facilitating significant original learning. For many educators, knowledge creation is the purview of others, while knowledge acquisition, consumption and, possibly, critique define the boundaries of the expected learning equation.
A Generative Philosophy of Adult Learning

Apparently, breakthrough has lacked a clear place in the dialogue of adult educators. Breakthrough and discovery are understood to happen at fortunate moments in the workrooms of higher education, think tanks, dedicated research facilities, and innovative industries. The breakthrough itself is seen as a marker of brilliance, remarkable effort, superior resources, or even blind luck. Yet creative, substantial breakthrough learning is rarely discussed and investigated as a process, competency, or role inside the field of education generally or in adult education specifically. Even the language describing it has not evolved to a point of clarity or acceptance. Given the persistent concern of adult education with the autonomy and inner-directedness of adult learners, this is a curious and important gap in our tradition.

Nor does the customary philosophical framework of adult education have a clear place for original, breakthrough learning. The standard typologies of philosophy or educational orientation are built around five general approaches or heritages: (a) liberal education and philosophical analysis, or cultivation of the intellect; (b) progressivism, pragmatism, or personal and social improvement; (c) behaviorism, logical positivism, or organizational effectiveness; (d) humanistic education, existentialism, or self-actualization; and (e) radical education, or social transformation (Darkenwald & Merriam, 1982; Elias & Merriam, 1980; Merriam & Brockett, 2007). Most of these discussions of adult education’s purpose have an underlying stance of learner as object, beneficiary, or consumer, and the educator, or field of education, as producer, director, or provider, even while the degree to which education shares the director or producer role with the learner may vary.
Even with learner-centered approaches to education, the underlying activity in education is generally the transmission by some means (perhaps dialogue, resource media, or facilitated experiences) of knowledge or values, or the directed development of the person or group. With the possible exception of some neutrally facilitated psycho-social development, the knowledge or understanding to be learned already exists in the world, and the learner is helped in some way to “get it.” The creation of significant, new understanding and human competence is not provided for in these orientations.

Darkenwald & Merriam (1982), discussing the “proper aim of education” (p. 44), describe a number of perspectives on the subject, most of them involving the transmission of knowledge, skills, values, truth, etc., or, alternatively, the directed development in the learner of various competencies and objectives like rationality, emotional and psychological growth, self-expression, awareness, new behaviors, attitudes, or relationships. The transmit-and-receive model of learning in these cases is often softened and stretched by the likes of andragogy or other encouragements to self-direction; constructivist perspectives; Socratic or facilitative techniques which set up mediator and learner “to reach the destination together” (Bekerman, 2007, p. 239) (a frequently disingenuous strategy since these methods tend to lead learners, by the facilitator’s “own clever sophistry,” to the facilitator’s “own version of truth” [Rachal, 2003, p. 61]), or perhaps the dialogic approaches of radical education objectives. Still, with the possible exception of the neutral facilitation of psycho-social growth or highly creative artistic endeavors, the transmission of some form of established knowledge or perspective usually remains the core agenda for adult education.
Where might the introduction of breakthrough learning which shifts knowledge paradigms fit in the philosophical context of adult education? Liberal education, or development of the intellect, might seem a close fit. However, the purpose underscores the educator-as-agent and learner-as-consumer structure, as illustrated in the standard perspectives on liberal education: “The aim of [liberal] education was to produce an intelligent, informed, cultured, and moral citizenry,” and “a liberal adult education perspective values the acquisition of knowledge, the development of a rational perspective, and the ability to analyze critically” (Merriam & Brockett, 2007, chap. 2, sect. 2, para. 6-7; see also Grattan, 1955). While traditional knowledge bases, rationality, and the intellect all may be engaged and developed in the course of a breakthrough learning project, these exercises are not the primary aim of such learning projects.

The progressive, pragmatic, self-actualizing perspective should also be considered as a possible perspective on original, breakthrough learning. This approach “placed more value in knowledge derived from observation and experience than from tradition and authority” (Merriam & Brockett, 2007, chap. 2, sect. 2, para. 11). This orientation includes “the use of scientific methodology incorporating problem-solving, activity, and experience-based approaches to instruction [and] a shift from teacher as authority figure to teacher as facilitator of learning” (Merriam & Brockett, 2007, chap. 3, sect. 2, para. 12). Still, the aim is instruction, or facilitating the acquisition of existing knowledge or uses for that knowledge. We can imagine that spirit of pragmatism is alive in many, if not most, learning projects that lead to breakthrough outcomes, but this philosophy does not currently encompass the essential aim and orientation of the self-directed learner on a journey of original, knowledge-paradigm shifting learning.
As for the other usual viewpoints on the proper aim of adult education, a potential fit is not apparent. Self-actualization, social transformation, and conditioned behavioral change do not seem to be key objectives for the independent learner who achieves breakthrough results outside the psycho-social domain. Yet, again, these may be important consequences or experiences associated with that learning, they may contribute to motivation, and these domains may even be the subject of a breakthrough learning project. Nevertheless, they do not seem to explain the essential objective or process of most knowledge-paradigm shifting breakthrough learning.

Since this application of philosophy has hardly been explored in adult education, and the inadequate understanding of the breakthrough learning process itself was the driver for this project, it is important to consider at this point what would be the philosophical context of original learning projects, and to describe that context where it does not currently exist. Indeed, Merriam and Brockett (2007) acknowledge that “working from existing schools of thought has its drawbacks….[such that Apps (1985) warns that] ‘the inclination is to become comfortable with this new-found intellectual home and stop questioning and challenging and constantly searching for new positions’ [pp. 72-73]” (chap. 2, sect. 3, para. 2). As we begin to understand more about original breakthrough learning and recognize it as an expression of adult education and learning, we need to engage in conversations about how to situate this learning in our philosophical framework. To that end, an addition to the schema of adult education philosophies is proposed: a generative philosophy of learning which draws on the insights of generative theory and philosophy in other fields where questions and propositions about the creation
and transformation of meaning and perspective have likewise risen to the level of significant philosophical concern.

As the Einstein case and other models of breakthrough and transformation indicate that the theory of transformative learning can be extended to describe original or breakthrough learning in knowledge domains, the lack of an appropriate corresponding philosophical orientation within adult education signifies the need to expend the standard set of five orientations to a sixth, a generative philosophy of learning. Summarizing these orientations succinctly, Darkenwald and Merriam (1982) described five appropriate aims for adult education: cultivation of the intellect, individual self-actualization, personal and social improvement, social transformation, and organizational effectiveness. Zinn (1990) developed the Philosophy of Adult Education Inventory (PAEI) in 1983 to serve as an instrument for adult educators who want to understand their own philosophical orientations. This model largely follows Darkenwald and Merriam’s, featuring liberal, behaviorist, progressive, humanist, and radical philosophical orientations.

The generation of new knowledge and capability, whether breakthrough or incremental, is an additional appropriate aim of adult education and learning, the purpose of which is to expand the knowledge pool within a field of inquiry, profession, or capability. Adult educators who support or have influence upon learning projects which ultimately have original outcomes are facilitators of generative adult learning. The educator may mentor the learner at a discrete stage in the project, or across the length of the project, may assist the learner’s search for extant knowledge or skills that would apply to the project, may help the learner to gain perspective or broaden horizons through creative and challenging conversations, or may take a number of other roles in support of
the generative learning endeavor. In any case, the successful supporter of a significant original learning project will take a learner-centered approach, for these learners are largely highly self-directed or autonomous in their learning requirements and behaviors. Even when the adult educator is not an expert in the field of the learner’s inquiry, if the adult educator is familiar with the orientations and processes typical of generative learning, he may be the most well-equipped individual in the learner’s circle to provide the kinds of facilitative support that the project may require at a given time.

A generative philosophy of adult education has roots in generative philosophy and theory in other fields, including generative philosophies of science (Kuhn, 1962, 2000; Riegel et al., 1992), Chomsky’s transformative and generative grammar within his generative philosophy of linguistics (Chomsky, 1965, 1966; Ludlow, 2011; Olson & Faigley, 1991), and Jackendoff and Lehrdahl’s (1982) generative theory of tonal music. In particular, Chomsky’s and Kuhn’s generative philosophies and theories share a genealogy with other theories and pedagogies of perspective transformation and transformative learning which have a significant basis in concerns of language and discourse. Other generative approaches in this family include Freire’s (1970) pedagogy of the oppressed (De Botton, Pulgvert, & Sanchez-Aroca, 2005), Habermas’s communicative action (1984) (see also McNamara, 2005; Morrow & Torres, 2002), and Mezirow theory of transformative learning (1991) (see also Cranton, 1994) which has helped to define adult education in recent decades.

Other instances of generative, knowledge- and perspective-building avenues of thought in various knowledge domains may be found. For example, Epstein (2006) describes generativity in the social sciences as specially facilitated by a computer

A generative philosophy of adult learning helps to situate the models of breakthrough and transformative learning described in the coming chapters, and supports the call—in the final chapter—for an expanded reach within the adult education field. As Apps (cited in Merriam and Brockett, 2007) cautioned us to not get too comfortable with a given set of philosophical orientations but instead to push for new understanding and perspective, adult learners who pursue learning project that evolve into generative work with original outcomes are likewise embodiments of the same spirit of seeking greater understanding and of discomfort with a concretized status quo. In this way, these learners and their projects personify a generative philosophy of adult education, and have much to teach us as professional facilitators of creative, original adult learning contributions.

**Expanded Arena of Contribution for Adult Education**

Psychologists, neuroscientists, philosophers, historians, journalists, and other curious sorts have made forays into understanding creativity, breakthrough, discovery, invention, transformation, and conceptual revolution. These explorers of breakthrough have contributed perspective, theory, and provocative questions. In fact, some of these contributions may support and inform this research into breakthrough learning process. Clearly the essential question, *how do we come to original and groundbreaking knowledge?*, is not the sole purview of any field. However, the contributions from the field of education have been comparatively light thus far.
But what if greater awareness and vision in the domain of adult education could increase the success of those independent learners Tough (1971) identified as atypically trying to gain original knowledge? What if bigger ideas about the role and potential of adult education could increase the number of those atypical learners by even small margins? Might some of the educational strategies for increasing and supporting creativity in children (Greene, 2006; Torrance, 1965/1976) suggest useful strategies for adult educators who want to support original and breakthrough learning in self-directed learners? What might these imaginative adult learners create that would transform the lives of our children’s children? Could the ability of adult educators to spot or entice “the continual interest in exploring and making discoveries [which is evidenced by the more creative] individuals” (Rothenberg & Hausman, 1976, p. 162) help these adults be more productive in their creativity, or perhaps increase the number of individuals who become highly creative persons? Might a well-grounded understanding of the process and experience of breakthrough learning have been of some assistance to Einstein as he labored unsuccessfully on his greatest project in the last 30 years of his work?

When educators use the term *breakthrough learning*, they generally refer to individual breakthroughs from ignorance or confusion to understanding in the context of knowledge transmitted from teacher or educational agent to student. When a student grasps a difficult concept or new perspective, this is an individual breakthrough, a significant achievement in the process of acquiring established knowledge. The experience can be exciting, important, and possibly even personally transformative. Without diminishing the value and pleasure of these critical breakthroughs, is it possible to set our sights even higher, to embrace and even expect original, creative breakthroughs
for learners? What would we need to understand about breakthrough as a learning process in order to describe a role for educators or students relative to the breakthrough phenomenon?

Groundwork has been laid in adult education for such questioning. The research foundation is particularly strong in the study of learner self-direction, independent learning, and transformative learning. Nevertheless, important work remains to be done to look inside the breakthrough phenomenon’s dimension of education and learning. This dissertation is meant to be another entry point into that work, to suggest that adult education may begin to incorporate the investigation and support of bold new learning into its tradition of inquiry and practice.

Breakthrough Learning Precursors in the Adult Education Research Tradition

The problem of breakthrough learning is inherently compelling, but where does it fit in the body of adult education research? Certainly there is a research gap: Independent breakthrough learners have made many of the vital, transformative contributions to the creation of human culture and capability, but their processes are under-studied and little understood. This gap has not gone unnoticed in the field. A number of adult education leaders have called for greater enlightenment in this area, little though that call may have been heeded.

Researchers and theorists interested in self-directed elements of adult education, including Tough (1966, 1971), Mocker and Spear (1982), Brookfield (1985, 1987), Mezirow (1985), Cavaliere (1988), Danis and Tremblay (1988), and Taylor (2000), have focused on the independent learner, with some note taken of exceptional outcomes. Candy noted that from the first stone tools of 3 million years ago and the development of
fire, shelter, and the wheel, humans and their ancestors made great advances through both likely and confirmed instances of independent, self-directed learning. However, research pointed at understanding “the process itself and the help sought out and obtained by learners” is scarce (Candy, 1991, p. 158). Though the past decade has seen improvements in this regard, the concern remains valid.

Much of the research into independent learning projects has focused on the average or undereducated learner’s independent learning projects. Cavaliere’s study of the Wright brothers’ learning project appears to be unique in its attempt to understand the process and experience of the high-achieving and paradigm-shifting autonomous learner. While Candy reports that Gibbons and Phillips did study twenty successful historical figures who became master performers in their fields, they specifically chose subjects who had not been formally educated beyond high school, and their observations were largely centered on the environmental and personal factors that predisposed these learners to be highly self-directed. That study did not make major contributions to a process model of the learning experience (Candy, 1991).

Merriam and Caffarella (1999) describe the model that resulted from Cavaliere’s study as “sophisticated” and “especially useful in that it describes both the stages of the learning process and the cognitive processes used throughout a major learning endeavor” (p. 298). Yet until this Einstein study, no further research has occurred to verify or extend the model (L. A. Cavaliere, personal communication, March 18, 2004). The purpose of this dissertation was not to verify theory, but rather, in the spirit of unbiased enquiry that is basic to grounded theory research methodology, the intent was to pick up the thread of
Cavaliere’s research approach and larger enquiry by exploring this new case of breakthrough learning for whatever contribution to theory would appear.

While validation was not, and could not be, the research objective, this was a valuable opportunity for comparison across cases and further reflection on established theory. Glaser & Strauss (1967), founders of grounded theory methodology, refer to this opportunity as “generation grounded in internal [and successive] comparisons” (p. 133). Glaser & Strauss also confirm the value of developing theory around a lightly researched phenomenon such as this one. “One strategy for bringing the generation of theory to greater importance,” they encourage, “is to work in non-traditional areas where there is little or no technical literature….escaping the shackles of existing theory and contemporary emphasis…. [and] opening a new area for inquiry” (pp. 36-38).

The results of Cavaliere’s research are in fact relevant to the findings in the Einstein case, as will be described in later chapters. Additionally, some of Cavaliere’s (1988) own suggestions for further research were addressed in this project. Naturally, her suggestions include “investigation of other historical case studies of this genre,” as “generalizations derived from multiple case studies could serve as a basis for a process model of adult learning” (p. 197). She notes specifically that the Wrights were not limited to “the organizing circumstance” (Spear and Mocker, 1984) but instead they “proceeded beyond . . . barriers and therein lies their genius. When they reached a scientific or technical impasse, they invented the solution. This behavioral phenomenon deserves further investigation” (p. 198).

Cavaliere invites further review of “the power of partnership” (p.199) in the learning project, an aspect not fully addressed in this Einstein study but considered to
some extent while examining the working relationship between Einstein and Mileva
Maric, Einstein’s fellow student and later wife, and the brief collaborations he undertook
later in his career. Cavaliere also noted the need to observe causes and patterns in
learning momentum. Finally, she wondered what additional research might discover
about personal variables within the learner, such as perseverance, and the effect on the
learning project.

Further directions for research in self-directed learning come from consideration
settings who are self-directed in their learning learn over long periods of time?” and
“How does the process of self-directed learning change as learners move from being
novices to experts in subject matter and learning strategies?” (p.312). Merriam (2001a)
says other areas for investigation include understanding how self-directed learning
persists over time, and how the learning context and the learner’s individual traits interact
in the self-directed learning situation. Of course, Einstein’s case involves learning
projects extending over many years, and the data offered insights about the learning quest
and his identity as a learner as he moved toward mastery and completion in his subject.

Merriam and Caffarella (1999) also complain of “insufficient critical dialogue and
use of the theory and models that have been developed, continual disregard of these
observations of previous researchers about recommendations for future research, and
predominant use of the quantitative or positivist paradigm” (p. 311) as contributing to the
delayed development of “a richer research agenda in self-directed learning” (p. 311).
While, again, the past decade has ameliorated these issues to some extent, this project
was conceived in part as a response to this situation. Others have suggested direction for
methodological approaches to such research. Brockett and Hiemstra (1991) note that “there is a need for further understanding of the social context in which self-direction exists” (p. 220). They also advise that “future researchers should continue to approach the study of self-direction using a variety of research methodologies,” and specifically they “recommend the development of historical . . . investigations to further support the conceptual base of self-direction” (p. 221).

Candy (1991) recommends that future research in self-directed learning call heavily on the interpretative approach. He criticizes the tendency in research on self-directed learning to create “lawlike generalizations and mathematically precise causal relationships” (p. 436). Candy also condemns methods that obscure individual and contextual differences of the learners while highlighting similarities and “external and publicly observable features,” or “assuming a linearity in the process” (p. 437). Similarly, Roberson & Merriam (2005) comment on how self-directed adult learning “is often a response to developmental issues of [a] particular life stage” (p. 284), which suggests the question, in Einstein’s case at least, whether developmental issues were important in the pre-adult stages of his independent learning project. Indeed, it turns out that his childhood development was quite significant to his autonomy as a learner and to what became his relativity learning project.

Candy specifically encourages “research into some of the elusive aspects of how learners organize, do and judge their self-directed learning activities” (p. 427), and he wants future investigators to give more “regard to the quality of learning or of its meaning to individual learners” (p. 436). He tells us that “what seems called for is a research orientation that emphasizes individuality, that acknowledges situational
variability, that takes account of the apparent random and serendipitous nature of human affairs, and that above all gives due prominence to the fact that people are active choosers” (p. 437). Again, Candy (1991) wants researchers to notice “personal purposes, intentions, and frames of reference,…[the kinds of] help sought and resources used, [as well as] outcomes arising from the learning encounter” (p. 438; see also Cavaliere & Sgroi, 1992; Ponton, Carr, & Derrick, 2004). Overall, he encourages research that truly takes a learner perspective (a perspective that both Candy and this researcher find to be paradoxically absent in much of the literature on self-directed learning). Finally, he makes specific recommendations for investigating the changing aspects of learning, as well as the learning experience during stages of moving “more deeply into the material” (p. 444). He wants researchers to shed more light on how learners choose and interpret assistance with their learning projects and value diverse learning resources, and to explain how an individual learner’s development of learning autonomy may evolve over time. This research project specifically and intentionally embraced, in one or more of its aspects, each of these suggestions and concerns.

The Individual Learner

The most significant contribution of this study could be the potential impacts on an individual learner. While this is one case study, adding to a single prior case study of a similar type and purpose, the resulting model is a result of comparing the patterns in the Einstein case not only with the model developed for the Wright brothers’ experience, but also to a number of other models and contexts of breakthrough learning. The common themes that resulted and informed the final integrated model provide additional strength
to these findings that can be useful to other learners who are engaged in passionate and personally meaningful learning projects.

Still, until a significant body of studied cases can be developed to understand breakthrough learning in light of learning processes, the small number of cases places a natural limitation on their value to an individual learner. However, these studies do provide a point of reference, and a pool of questions, that contribute to understanding the learning experiences of other independent breakthrough learners. Merriam (2009) defends the merits of even a single case study, saying:

Much can be learned from a particular case. Readers can learn vicariously from an encounter with the case…. [and] since the general lies in the particular, what we learn in a particular case can be transferred to similar situations. It is the reader, not the researcher, who determines what can apply to his or her context. (p. 51)

Gruber & Wallace (1999) specifically encourage the case study approach for research in creativity and breakthrough:

The creative person is unique, developmental change is multidirectional, and the creative person is an evolving system. The necessary uniqueness of the creative person argues against efforts to reduce psychological description to a fixed set of dimensions. The creative person is not conveniently “far out” along some well-charted path: She or he is unique in unexpected ways. (p. 93)

Keeping in mind the individual learner’s opportunity for benefit and application to future learning projects is also a personal priority of the researcher, who has worked as a professional executive coach for over a decade, and as a mentoring manager, facilitator, and in one form or another a developer of professional and personal capability for thirty
years. This experience, particularly in the last decade of continual focus on the personal and work-applied self-directed learning work (with personal and work-applied transformative results) of many sorts of professionals and private individuals, naturally instilled concepts and mental models of learning, change, and breakthrough in the mind of this researcher. Applying the reflexivity of the aware grounded theoretician helped to keep these experiences out of the central light while looking at the Einstein experience to see what was freshly, uniquely there to be understood about this particular learner.

However, the nature of the constructivist approach to developing grounded theory allows the researcher to acknowledge that these prior experiences and reflections had to be part of the researcher’s inner guidance as she noticed patterns and found meaning in the concepts coming out of the Einstein data (Charmaz, 2005; Glaser, 2002b; Glaser & Holton, 2004). And once that data had been mined and theoretical concepts emerged and were integrated, the central light of research shifted to comparing and illuminating the findings in the contexts of other theory and other fields. At this point, the experience and concerns of the professional facilitator of adult transformative learning came into clear play as further meaning could be found within the Einstein case by comparing his process to the process models in other cases and fields.

This research was conceived with a focus of understanding Einstein’s work and process not in terms of transformative learning but in terms of self-directed learning, just as Cavaliere’s work was tuned to the self-directed processes of the Wright brothers. (Cavaliere’s work was completed before transformative learning theory swept the field of adult education.) Early on, the parallels with transformative learning theory appeared, but more as a point of curiosity than a research focus. This work was to be about the process
of breakthrough in knowledge domains, the learning actions, experiences and contexts that led to revolutions in a field of knowledge. It was not meant to be about personal transformation. However, over time and as the research came closer to conclusion the pattern and nature of Einstein’s experiences reeked of transformative principles and implications, and gradually the research picture came to light as an intersection of self-directed and transformative learning, such that breakthrough learning (at least Einstein’s and experientially for many others) is a phenomenon in which self-direction and transformation can barely be teased apart, just as it is only with careful effort that some of the perspective transformative experiences and cycles in Einstein’s learning journey can be differentiated as personal or professional.

As a result, this coach and researcher clearly wants for others’ learning journeys to be even more successful as a result of better theory, richer examples, and truer stories of breakthrough experiences, and sees learning journeys as highly individual and personal experiences, notwithstanding the social contexts, environments, and implications that are critically important to each journey. A better map of the territory of the processes and experiences of successful independent learners, which was a central goal of this research, will support future creative learners in any setting by helping them anticipate patterns, obstacles, and opportunities in their own projects. A greater understanding of independent learning may assist these learners in being more self-aware as learners, further skilled at self-facilitation of their learning process, newly able to guide others to support them appropriately, and able to make use of strategies other independent learners have used for breaking through barriers in their projects. One independent learner
achieving breakthrough in part due to a greater understanding of the process could, once again, change the world.

Daring to Understand

There is a surprising amount of resistance to this idea that we can explore and better understand the processes of discovery and breakthrough. Stachel (2002b), for example, developed a model for Einstein’s discovery of special relativity, one which attempts to reconstruct the path of scientific thought processes and the acquisition of scientific knowledge Einstein followed to get to the special theory of relativity. (He did this from the standpoint of knowledge scaffolding rather than from the perspective of a model of behavioral processes, or learning strategies, used to solve the learning problems, which this research seeks to do.) However, Stachel was clear on his viewpoint that aspects of the breakthrough process are unknowable, and quotes Einstein’s own concern in this regard:

Let me emphasize that no such account can hope to encompass those elements of the creative process that Einstein referred to as “the irrational, the inconsistent, the droll, even the insane, which nature, inexhaustibly operative, implants into the individual, seemingly for her own amusement,” for “these things are singled out only in the crucible of one’s own mind.” Yet one may draw courage for the type of conjecture I have in mind from another remark of Einstein’s: “A new idea comes suddenly and in a rather intuitive way. That means it is not reached by conscious logical conclusions. But, thinking it through afterwards, you can always discover the reasons which have led you unconsciously to your guess and you will find a logical way to justify it. Intuition is nothing but the outcome of earlier
intellectual experience.” I shall discuss only this intellectual, logical side of Einstein’s struggles. (pp. 158-159)

Stachel gathered courage for his own inquiry into the mind of Einstein, saying, “I believe that the problem of how Einstein discovered the special theory of relativity falls into this category of ‘puzzling questions’ that are ‘not beyond all conjecture’” (p. 157). In the same vein, the present study stands on the notion that a deeper understanding of breakthrough learning is possible, and asserts that the crucible of the mind is “not beyond all conjecture.” This research was not an undertaking to comprehensively understand the full experience and process of coming to eureka moments. Rather, the goal was to approach more closely the internal and behavioral experiences of a breakthrough achiever in order to better illuminate the process for others. As Einstein made clear in 1934, “The years of anxious searching in the dark, with their intense longing, their alternations of confidence and exhaustion and the final emergence into the light—only those who have experienced it can understand that” (cited in Robinson, 2005, p. 66).

Einstein does offer several words of encouragement for anyone seeking to understand his processes and experience. For example, Cohen, 1955/2005, relates that Einstein saw a place for later students of his work to gain some insight into his processes:

Einstein said most emphatically that he thought the worst person to document any ideas about how discoveries are made is the discoverer. Many people, he went on, had asked him how he had come to think of this or how he had come to think of that. He had always found himself a very poor source of information concerning the genesis of his own ideas. Einstein believed that the historian is likely to have a
better insight into the thought processes of a scientist than the scientist himself.

(p. 217)

Einstein believed that the key to appreciating his work lay in an understanding of his mind and thought processes. Susskind (2006) considers this point:

Einstein once said, “The essential thing in a man like me is what he thinks and how he thinks, not what he does or suffers.” He might also have said, “The greatest satisfaction is not in what I found but in how I found it.” (p 178)

Einstein may even have yielded over time from his stance against probing the “crucible of the mind,” for he remarked to Max Wertheimer, the father of Gestalt psychology: “I am not sure whether there can be a way of really understanding the miracle of thinking, [yet] certainly you are right in trying to get at a deeper understanding of what really goes on in a thinking process” (Wertheimer, 1944/1982, p. 227). Better still, he offered his own defiant spirit and beliefs about attempting the unlikely task. He said, “I have little patience with scientists who take a board of wood, look for its thinnest part, and drill a great number of holes where drilling is easy” (Clark, 1971, p. 3).

Einstein’s gift to humanity, or one of them, was in drilling where the drilling was not easy, and persevering to unveil large swaths of the inscrutable. Part of his fame undoubtedly comes from his ability to embody the way we all seem to have been born to solve mysteries and to revere them, to embrace the hidden nature of life’s wonders while also straining to see what is really there. Over a lifetime, Einstein presented for our own wonder an unfolding story of time and space, light and gravity, the majesty of vast scales and unthinkably minute ones. And while he completed the Copernican heist of human centrality in the cosmos, in return he took us out of ourselves.
Einstein asked us to think deeply about relative perspectives and how fundamentally they can change both experience and notions of truth. He gave us wings, or jet-packs, to ride on light waves and return younger than when we left. He invited us on a grand adventure to ride along on those light waves, an adventure that eventually allowed us to approach a singularity where, if we should venture too close, our light-stream transport could be swallowed forever into the belly of a black hole. He made us squint to see that our light wave isn’t just a wave but also a torrent of light packets. Then, of course, those packets, or quanta, led us down a rabbit hole of craziness where every observation of a thing pushes it in another direction, an unwinnable multi-directional pinball game resulting in an unreal reality, or a number of them.

We have always wanted to know what we don’t yet know, and have never ceased to reach for the apple, or wonder what would happen if someone else was bold enough to reach it for us. We were always waiting for the gift of knowing what was behind the mystery at hand, and we wait for those that are still to come. When the theories of relativity and quantum physics arrived, as when the first airplane took flight, and when we took our own first flight, we embraced both the unveiling and the continued mystery. We could embrace the wonder and intense curiosity not necessarily because we shared the capacity or persistence of the discoverer, but because we were ready for the breakthrough itself, the mystery unveiled and the view it afforded. Man wasn’t born with wings, but now we fly. We lack even the vision of eagles, but we peer through billion-year star histories, and we sling infinitesimally small bits of matter at other tiny bits in almost unimaginably large colliders, because individuals not only wondered about and dared to ask enormous questions, but because we continue to dare to answer them.
It is this asking and answering which this research, like Cavaliere’s and others’, sought to understand in some measure. It is time, at this point in history of the art-science of education and learning, to dare to think more seriously and imaginatively about breakthrough learning processes, about fundamentally creative and original learning that is big and bold and wild, and looks nothing like education or learning as routinely conceived but which is so important that humanity invests great hope in these processes to continue to carry us over the shoals and forward.
CHAPTER II

A MODEL OF BREAKTHROUGH KNOWLEDGE CREATION

*When I examine myself and my methods of thought, I come close to the conclusion that the gift of imagination has meant more to me than my talent for absorbing absolute knowledge* – Einstein

Model Overview

This chapter and the next two present and elaborate a model of breakthrough knowledge creation grounded in the study of Einstein’s learning processes as he developed the theories of relativity. This chapter describes the integrated model, with emphasis on original learning as a higher-order function in a taxonomy of learning. An orientation in transformative learning, independent and self-directed learning, and some other relevant constituents of adult learning theory, as well as some features and distinctions of the breakthrough phenomena, and conditions and catalysts of breakthrough, also support this model.

The model, illustrated in Figure 1, features a process consisting of key elements of Mezirow’s (1991) transformative learning theory, though in this case the focus is on a knowledge (or technical, or otherwise non-personal) learning domain. (Important distinctions must be made here. *Technical learning* is not limited to the fields of contemporary technology, but is used to distinguish any professional domain or knowledge field, e.g. visual arts, economics, or journalism, as separate from the human-experience paradigm changes involved in individual or social transformation, e.g. personal and social belief structures and behaviors, within which transformative learning is currently understood to be limited. Likewise, *non-personal transformative learning*,}
knowledge domain transformative, field transformative, and external transformative learning are similar labels used to make the same distinction. Also, in this case, personal domains—as opposed to non-personal—should not be assumed to be limited to individual experience, but extended to the personal, human, experiential impact on socio-cultural domains which has been the larger focus for transformative learning theory in recent decades. Thus, the model presented here is focused on extending principles of transformative learning beyond examining individual beliefs and challenging the mores of human interaction; this model embraces paradigm shifts in humanity’s knowledge, capability, or form of expression, and in this sense highlights the technical, knowledge-domain, external, non-personal, or extra-personal type of breakthrough. These are all ways of making the contrast against the traditional objects of transformative learning theory. (See the glossary, in Appendix A, for more definitions and descriptions.)

The process model presented here (illustrated in Figure 1) is supported by principles of self-directed or autonomous learning, and emphasizes the imperative that the breakthrough learning process must start and carry through in a context that is highly meaningful to the individual learner, for this context will be the central source of motivation, direction, and orientation throughout the project. While each of these elements will be discussed in more detail, the third element of the process, persistent interaction of the learner with the learning problem, will be unpacked with particular care and elaboration, since this is where the bulk of the learning action will take place. The model-guided journey through Einstein’s learning project in later chapters will feature both a process-level view (embodied chiefly in these interaction and integration elements), and a perspective transformation view, which is represented by the full process
in Figure 1. Those two views, learning process and perspective transformation, are actually linked, as in experience one feeds the other.

![Integrated breakthrough learning model](image)

**Figure 1.** Integrated breakthrough learning model for original learning that transforms a knowledge domain.

The third element (interaction), together with the fourth (integration), represents the process focus that is inherent in much of the research into self-directed learning. The first and second elements (the disorienting experience, which here is a catalyzing experience that includes wonder and an implacable curiosity, and critical reflection) are outstanding features of transformative learning theory, though the entire process mirrors the central flow of standard transformative learning as well as some common elements of self-directed or autonomous learning. This perspective on breakthrough learning
illustrates an intersection of transformative and self-directed or autonomous learning that is already known in adult education. Cranton (1994) notes:

Self-directed learning is interwoven with transformative learning….To some extent, an individual must either already be self-directed or have the skills to engage in self-directed learning if transformative learning is to be possible. Self-directed learning can also be described by the process by which learners question their assumptions and contemplate ways in which they can change their worlds. And, finally, increased self-directedness is likely to be a product of the transformative learning process…..[Further,] the more autonomous a learner is, the more likely he or she would be to engage in transformative learning.

Likewise, participation in the process of transformative learning further increases autonomy….Candy writes, “an autonomous person is able to assent to rules, or modify or reject them, if they are found wanting” (1991, p. 113). (pp. 59-60)

The central point of this integrated model is that an independent breakthrough learning project (a) begins with a meaningful catalyst in a context of wonder and relentless curiosity—a disorienting experience of some sort in a highly meaningful and personally engaging context; then (b) the learner must begin to try to make sense of this experience through critical and imaginative reflection; and (c) interact with the resulting problem persistently with a quality of attention that can be described as transformative (a concept which will be developed in coming chapters) over a considerable period of time, the result of which is a learning posture that is most conducive to original, creative, and breakthrough learning results which can (d) be actualized and integrated into a final learning product of value to the knowledge domain.
The initial step, the meaning phase of the model where a disorienting experience, or catalyst, occurs, is where desire lives. Einstein’s burning desire to understand the mysterious laws of the universe seemed directly related to the meaning that the discovery held for him: the connection with the divine, the identification with a scientific tradition and community of similar thinkers, and the challenge of solving an important puzzle with implications far beyond himself. This stage represents the powerful engine that is a powerful passion to know, solve, express, create, or achieve. This is the engine that drives the breakthrough learning process.

The meaning phase plays another role, especially when combined with reflection, which is navigation through the breakthrough learning experience. If the function of desire and passion is to want something badly enough to engage in a rigorous learning process of exploration, aggravation, defeat, and insight, the navigation function is about having a clear focus on the object of that desire, a focus strong enough that the object seems to develop a homing beacon toward which the learner directs and tests his steps. Personal meaning at a significant, foundational level is associated with beliefs, values, and perceptions that have an orienting effect on the learner, as will be clearly seen in the Einstein narrative in later chapters, as guiding beliefs, beloved philosophies, and tenacious prejudices led him down alleys that were either fortuitous or unfortunate all along his learning journey.

Victor Frankl (1959/2006), creator of the philosophical and psychological model of logotherapy, describes this kind of meaning-driven navigation system:

Don’t aim at success—the more you aim at it and make it a target, the more you are going to miss it. For success, like happiness, cannot be pursued; it must ensue,
and it only does so as the unintended side-effect of one’s dedication to a cause greater than oneself… Happiness must happen, and the same holds for success: you have to let it happen by not caring about it. I want you to listen to what your conscience commands you to do and go on to carry it out to the best of your knowledge. Then you will live to see that in the long run—in the long run, I say!—success will follow you precisely because you had forgotten to think of it.

(2006, Preface, para. 5)

Frankl’s instruction to listen to the commands of conscience could also be construed, in the context of his writing and from the example of Einstein, to mean more than heeding a moral compass. Those commands of conscience would require listening to the demands of the meaningful undertaking. This is the kind of navigation system which guides a breakthrough learning project through that long, long run of attention, interaction, and finally integration. His instruction also speaks to a quality of attention that is featured in the next chapter: the ability to remain open and to let go of the outcome, either as a standard way of working or at intervals in the project.

The reflection stage of the breakthrough learning model appears as a separate phase, but actually represents an activity that occupies the learner through every phase of the project, as it did Einstein. Reflection is absolutely not limited to a phase or position in the process, or to the critical approach. In fact, theorists have long debated about the nature and location of reflection in the learning process. Newman (2011), calls reflection “an intellectual activity concerned with imagination, intuition, and insight” (p. 315), which is the key meaning assumed in this model along with the presumption that
becoming aware of and working critically with underlying assumptions, or meaning perspectives, is an important part of the road to insight (Cocteau, 1985).

Reflection is a complex experience with dimensions that may seem contradictory. Reflection may be primarily rational and objective, as in Mezirow’s (1991) conception of critical reflection, or it might be primarily emotional and subjective. It might be a deeply intuitive process, or, instead, strictly logical. Reflection may be highly imaginative or processual, critical or appreciative, visual or verbal, more or less conscious, and more or less articulate. Any or all of these reflective qualities may be present in an individual experience of reflection on the premises, meanings, and implications of a learning problem, whether personal or non-personal. Einstein’s work certainly contained a major and continual reflective component. It was primarily but not exclusively visual, both critical and appreciative, varying from highly imaginative (as in his “dreaming” times) to orderly and processual (as when he wrestled with problems of higher mathematics). Any manifestation of reflection may be useful to the breakthrough learning project, and it may be that a learner who is well-practiced in a variety of reflective processes is particularly well suited to succeed with personal or non-personal transformative learning work.

Reflection, for Einstein, and for many others, seems wrapped up in the experience of the catalyst, the disorienting experience, and follows into the process of interaction and integration, sometimes continuously, sometimes intermittently. Reflection occupies a distinctive position, its own stage, in the process model because it is a necessary condition, a fundamental piece of the process. Mezirow (1991) gives reflection a position between disorienting dilemmas and the many steps that follow in his transformative learning theory. It makes sense to put it there, if it must be put somewhere—and it must.
If reflection has not begun at the point of the catalyst, it must take place at some point before significant insight is achieved in the interaction stage. Einstein’s breakthroughs came from critical insights, which came from seeing the underpinnings of the situation differently, even when it was very hard for him to do so, either cognitively, philosophically, or emotionally. Had critical reflection not occurred, no gap would have been made for the light of insight to get through.

The long and winding interaction phase that follows a meaningful catalyst and orienting reflection, and is the focus of the next chapter, is the propulsive function in the process. This is where most of the attention to the project is located. A learner may want quite badly to come to an understanding or solve a problem, and may reflect imaginatively and critically on the problem, but without actually attending to the learning problem over time, taking action and applying a diligent scrutiny, the problem remains a curiosity and never becomes a productive project. However, there is a definitional assumption in this model that a catalyzing, disorienting experience in a deeply meaningful context, with applied imaginative and critical reflection, likely results in a magnetically attractive learning problem, as was clearly the case for Einstein. As such, the concept of diligent attention in this case does not draw primarily on duty or will, but on the natural flow of attention toward a labor of love. Victor Frankl (1959/2006) describes this level of meaning:

[Logotherapy] focuses on the meaning of human existence as well as on man’s search for such a meaning….This striving to find a meaning in one’s life is the primary motivational force in man. That is why I speak of a will to meaning in contrast to the pleasure principle…[and instead of] “striving for
superiority”….This meaning is unique and specific in that it must and can be fulfilled by him alone; only then does it achieve a significance which will satisfy his own will to meaning.” (Part II, para. 5-6)

Interaction with the problem involves finding out what to do, literally, with that passionate desire to attain something meaningful. This is the stage of going after it (in one or more of three modes, which are discussed in upcoming chapters), of taking action after action, right turn after wrong, encountering a brick wall after a long glide, in order to create solutions or achieve insights that will be integrated into a final product in the integration stage of verification and actualization.

In the course of Einstein’s learning journey, he experienced a series of meaningful catalysts, or disorienting experiences. Significantly, in his youth he faced a number of disorienting dilemmas, both personal and project-related, which revealed and developed a learning project that would later result in two theories of relativity and an inaugural cosmology of our universe. He engaged in project-orienting critical reflection at the point of each catalyst and throughout the stages and decades of his project. He followed a learning journey, the details of which will be given considerable attention both in theoretical form, in these early theory chapters, and in narrative form following his actual experiences, in later chapters. That learning journey, primarily illustrated by the activities of the interaction stage, featured important learning behaviors and experiences (like modeling, slogging, despairing, and reviewing) and qualities of attention (including a playful orientation, imagination, and engaging in insight-catalyzing behaviors like playing music and hiking when not directly engaged in learning work) which directly supported the breakthrough process. His final steps of integration, including validation,
publication, and seeking further validation after publication, completed a full course of
the breakthrough process.

However, his learning journey took him through multiple breakthrough processes. At
the macro level, Einstein’s journey to and through relativity can be seen as a single
breakthrough process. The journey of achieving the special relativity theory can be seen
as its own breakthrough process, as can the next stage, the creation of the general
relativity theory. Below the level of theory achievement and publication, his project took
Einstein through a number of perspective transformations, or breakthrough processes,
each of which ushered him into either an important next stage or level of understanding
in his project. Therefore, this integrated model view should be seen as a highly simplified
representation of a breakthrough learning experience that was actually multi-layered and
dimensional, recursive and interactive. It will serve as a guidepost, though, as the
elements of the model are developed, and as the theoretical underpinnings that support
this grounded theory are described.

The four stages of this process model are supported by the conditions of self-
direction, or autonomy, and a learning environment which is either supportive or
tolerable. As discussed, self-directed learning is a central element of transformative, or
breakthrough, learning. The history of original breakthrough learning is so heavy with
individuals and partners working self-framed, self-motivated, and self-directed projects
that the example of Einstein’s vehement self-directedness is hardly remarkable in this
company. And while the effects of conditions of the learning environment are less well
documented and understood than is self-directedness in breakthrough learning, Einstein’s
example and others illustrate the important effects that the environment has—from
formal learning arenas to informal relationships and resources that make up the autonomous learning environment—in shaping a learner and a learning project, even though the effects are at times paradoxical.

Self-Directed Learning Matrix and Typology

The central concepts of this domain breakthrough learning model can also be represented and illuminated in the form of a matrix and a typology of self-directed learning, depicted in Table 1 and Figures 2 and 3, below. Knowledge-transformative breakthrough learning exists within a range and dimension of adult learning types, as illustrated in Table 1 below. Breakthrough learning as seen in the cases of Einstein and the Wright brothers belongs to the context of knowledge domain learning, or learning that pertains to a knowledge base or capability within a broad field, or segment of that field. This is not personally (individually or socio-culturally) transformative learning, though that may be an ancillary effect. Within the context of domain learning, breakthrough learning is an exceptional form, or level, of original learning contribution within a domain.

Table 1 explores the distinguishing characteristics of domain-transformative breakthrough learning in a knowledge or capability domain when compared to incremental original learning or the acquisition of knowledge and skill within the domain, and in comparison to analogous levels of learning within the personal learning domain. Of note, the transformative, or breakthrough, level of learning in the domain and personal contexts seem to be a necessarily highly self-directed or autonomous form of learning, given the intensity of meaning, commitment, effort, and perseverance that is expected in either of these highly creative and disruptive forms of learning.
<table>
<thead>
<tr>
<th>Type</th>
<th>Motivation</th>
<th>Context</th>
<th>Product</th>
<th>Defining Action</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain</td>
<td>Self-directed</td>
<td>Domain / Personal*</td>
<td>Knowledge-Capability / Behavior-Attitude</td>
<td>Acquire / Create*</td>
<td>Acquire / Create* Meaning</td>
</tr>
<tr>
<td>Transformative Learning</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(e.g. substantial discovery)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domain</td>
<td>Either / mixed</td>
<td>Domain</td>
<td>Knowledge-Capability</td>
<td>Create learning (incremental knowledge-capability creation)</td>
<td>Either / mixed</td>
</tr>
<tr>
<td>Original Incremental Learning</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>(e.g. knowledge production)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Domain</td>
<td>Either / mixed</td>
<td>Domain</td>
<td>Knowledge-Capability</td>
<td>Acquire learning (increase knowledge - skill)</td>
<td>Acquire domain perspective</td>
</tr>
<tr>
<td>Acquisitional Learning</td>
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<td></td>
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<td>(e.g. study)</td>
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</tr>
<tr>
<td>Personal</td>
<td>Self-directed</td>
<td>Personal</td>
<td>Behavior-Attitude</td>
<td>Create learning (transform ways of being)</td>
<td>Create (transform) pers. Meaning perspective</td>
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<tr>
<td>Transformative Learning</td>
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<tr>
<td>(e.g. coming to appreciate diversity)</td>
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<tr>
<td>Personal</td>
<td>Either – mixed</td>
<td>Personal</td>
<td>Behavior-Attitude</td>
<td>Create learning (move toward new ways of being)</td>
<td>Either / mixed</td>
</tr>
<tr>
<td>Meaning Incremental Learning</td>
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<tr>
<td>(e.g. incomplete transformative learning)</td>
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</tr>
<tr>
<td>Personal</td>
<td>Either – mixed</td>
<td>Personal</td>
<td>Behavior-Attitude</td>
<td>Acquire learning (increase awareness of ways of being)</td>
<td>Acquire personal perspective</td>
</tr>
<tr>
<td>Acquisitional Learning</td>
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<tr>
<td>(e.g. self-awareness)</td>
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*Domain=Field, Knowledge Base, Human Capability; Personal = Individual or Socio-cultural; Create = Produce or Transform
A simpler view of the breakthrough learning context is available in Figure 2, which depicts self-directed learning in a way that differentiates between the pursuit of extant knowledge and the pursuit of new knowledge or perspective. The typology distinguishes between levels of new knowledge creation, and depicts the outcome of the generative form—or new knowledge and perspective seeking form—of learning as either in the personal or social-cultural domain of transformative learning or in the knowledge domains of breakthrough learning (a knowledge domain could be physics, psychology, transportation, architecture, or any other field of inquiry or human undertaking).

**Figure 2.** A typology of self-directed learning leading to breakthrough.

An extended typology of self-directed learning, depicted in Figure 3 as a further exploration of the typology represented in Figure 2, considers the variety of forms and purposes that self-directed learning may take with respect to the knowledge domain or personal contexts. Each context branches toward either acquiring or creating learning, the
latter of which includes both the incremental and breakthrough—or transformative—level of learning achievement.

Within the personal learning context, the learning is distinguished by the relevance to personal meaning, which drives attitudes, behaviors, and other manifestations of various ways of being as in individual or within a social context. The standard transformative learning theories are oriented around the personal transformative learning level, where meaning perspective transformation occurs in a fully-integrated manner leading to obvious and felt changes in behavior and attitude, or perspective. As understood within transformative learning theory, perspective transformation often occurs as part of cumulative meaning scheme transformations, or transformations of personal knowledge schemes, beliefs, and attitudes at a level below significant perspective transformation. This level of meaning scheme transformation is represented in the incremental level of learning within the personal learning context, as are experiences under the umbrella of transformative learning which are not—or not yet—fully realized. (See Chapter III for a discussion of scale and completion in transformative learning of both the personal and domain types.)

The lower, or acquisitional, level of learning in the personal context, parallel to knowledge and skill acquisition in the domain learning context, represents meaning-related learning that does not entail challenging and creating existing meaning toward replacing that meaning with new meaning schemes or perspectives. Increasing self-awareness is represented at this level, when that self-awareness is not developed in a situation of disorientation, critical reflection, and perspective replacement. For example, we may become aware, by personal observation or external input, that we work more
productively in groups than alone, that we are uncomfortable when working toward vague objectives, or that we tend to take a fretful position when asked to be responsible for the outcomes of others. We may acknowledge these tendencies and have, as a result, a more fully formed view of ourselves, internally or externally, yet experience no crisis about our behaviors, attitudes, or feelings as a result, spend no significant amount of time processing this new information reflectively, and make no significant changes in our behavior as a result of our awareness. In this example, we have acquired new meaning-related knowledge but have not entered into any transformative learning work as a result.

Figure 3. Extended typology of self-directed learning.

Another form of personal learning at this level, which may be possible only in the context of childhood, is the acquisition of initial meaning schemes and perspectives. If, in personal transformative learning, we are meant to examine and eventually replace that
perspective with one that is new or changed, we must have first acquired that perspective. The Einstein case, studied from early childhood because of the obviously substantial influence of childhood experiences and learning work on his eventual breakthrough discoveries, is rich with examples of first acquisition of meaning perspectives in both the personal and knowledge domains. His learning journey thereafter depicts Einstein extending, challenging, defending, shifting, and transforming many of these early-acquired perspectives. At the domain level, he continued to acquire meaning perspectives (philosophies, viewpoints, beliefs, and orienting opinions) into adulthood as he was exposed to new levels, realms, and defining ideas within his field, and exposed to other fields which would inform his work. At the personal level, however, it may be that in childhood we develop at least assumptive perspectives on most aspects of life and relationship (e.g. work, marriage, parenting, relating to unfamiliar cultures, etc.), even if we will not encounter them in a direct, active personal manner until later in life.

This self-direction-centered view underscores the essential function of self-direction as a condition of breakthrough learning, and also the close relationship between operational processes of self-directed learning (discussed in Chapter V in comparison to the transformation-centric model of breakthrough learning described in this chapter) and the meaning-shifting processes of transformative learning. In the review of relevant adult education theory that follows, self-directed learning and learning environment are topics which relate back to these foundational conditions of breakthrough learning. The other topics (original and transformative learning, workplace learning, andragogy, and learner motivation) also have some bearing on the foundational conditions, but are more relevant
to the model’s context (originality and breakthrough in learning) and to the four process steps.

Original Learning

A fundamental principle underlying this model of breakthrough learning is the notion of original learning, of which breakthrough learning is a subset. However, as discussed in the introductory chapter, original learning is not a well understood or common topic of consideration in adult education, so it deserves to be developed in a theoretical context. Original learning not only differentiates between transmitted learning and original, contributive learning in a taxonomy of learning types, it sets up an expanded perspective for transformative learning, which until now has been concerned only with personal and socio-cultural perspective transformations, or breakthroughs. Original learning also defines a learning experience that is not only like none other to the learner, but is one on which human society and culture has come to depend.

A model of learning types, in a hierarchy from transmitted knowledge and skills to domain-transformative breakthrough learning, is illustrated in Figure 4. Einstein’s learning project featured learning at each of these levels. Each level of learning has the potential to contribute to the next.

However, similar to Bloom’s taxonomy of learning objectives (Marzano & Kendall, 2007), this is not a model of necessary steps from the lowest level to the highest. A learner might critique acquired knowledge before, or without, applying that learning outside the learning environment. Or a learner might contribute a breakthrough learning result without, or before, contributing other new knowledge at a lower, or incremental
level. In all, this picture aims to point out some of the functions of an ecology of learning which are not always obvious or attended to in the field of education.

Consuming (or acquiring through transmission) knowledge and skills, employing that learning, and possibly critiquing it, are the commonly addressed purposes of learning in the field of education. Nevertheless, meaning making, along with critiquing, has a catalyzing function, pointing the learner toward more creative uses of learning. At the next level, incremental knowledge contributions—a clearly creative feature of learning—act to extend and evolve a knowledge domain. And, finally, breakthrough original learning is by definition transformative of a knowledge domain, and sometimes of humanity’s quality of experience and capability.

Original learning moves beyond the teaching-learning paradigm (including autodidacticism). Instead, it situates learning in an exchange between the learner and any catalyst or resource, internal or external, which may cause her to ask or answer a new question, or answer an old one differently. The question is the vehicle of investigation and learning, and, particularly in the case of self-directed original learning, the learner is often both the vehicle’s designer and driver. Anything may serve the process of reaching original learning, including teacher-moderated established learning (established learning being the acquisition of extant knowledge). Petrie (1981) differentiates between established learning and original learning, calling the activities “grasping the old-knowledge horn” or “the new knowledge horn,” the latter process referring to “how we can generate ‘knowledge variants’ concerning brand-new areas and test the validity of these variants to see whether they deserve to be called knowledge” (p. 29).
Original learning suggests that education (encompassing all forms, not just the formal) is actually a bi-directional process in which the learner (knowledge consumer) sometimes acquires learning from the great knowledge stockpile, and at other times the learner (knowledge producer) adds something fresh back into the store. From that perspective, embracing original learning as a form of education, views about roles, transactions, and purposes in education may be reconsidered. When Livingstone (2007, p. 203) asserts that “the continuing acquisition of knowledge and skills is probably the most distinctive feature of the human species,” the scope of the declaration suggests the inclusion of original learning, but the full context of the Livingstone article—not at all surprisingly—is fixed solely on transmitting extant understanding.

Education and learning are so tightly associated with established learning that a crowbar seems to be required to open up space to consider that the continuing production...
of knowledge and skills might be equally, if not more, definitive of our humanity, and just as genuinely described as a process of learning and education. If formal education is “the preferred daughter of educational theorizing” and nonformal education is “relegated to the position of an exotic or poor relative” (Bekerman, Burbules, & Silberman-Keller, 2007, p. 2), where is the place card set for original learning? Smith (2007), though apparently speaking on behalf of learning as an existing-knowledge transaction, suggests a stance that is wide enough to embrace the value of original learning to the full educational landscape: “We need…to adopt ways of thinking and acting that have at their core an informed commitment to human flourishing in its fullest sense” (p. 12).

Breaching expectations and exploding old paradigms, breakthrough learning is the extraordinary form of original learning. Exceptional, breakthrough original learning “goes beyond predefined targets [and] redefines the game” (McDermott, 2007, p. 291). Galileo, initiating the serious practice of observational astronomy and, by many accounts, fathering modern science; and Newton, describing gravity and the laws of motion while opening the doors to classical mechanics, each redefined the domain of physical science. Adam Smith, helping to found political economics and introducing capitalism; Marx, playing a key role in the development of socialism and communism, and Keynes, re-conceiving macroeconomics, business cycles, and the potential of fiscal and monetary policy, all redefined the world of socio-economics.

Despite the exceptionality of these paradigm-shifters, original learning is not uncommon. It is usually incremental and gradual. This measured progression of knowledge is often the result of the iterative efforts of researchers, and the natural innovations of thoughtful practitioners and competitive industrialists. Furthermore, the
important contributions of persistent, moderate gains in knowledge domains should not be trivialized by the fireworks of less frequent breakthrough learning. Each type of original learning depends on the other for energy and direction, and the thrill of discovery is among the finest of human experiences regardless of the scale of the finding. Still, the processes and experiences of incremental versus breakthrough learning may be quite different. Indeed, they are poles apart in terms of how well they are understood, though the gap is slowly narrowing. This research aims to narrow that gap a bit further.

On the surface, the process of coming to achieve breakthrough learning may seem self-evident. Frequently there are established systems and proven methods for the regular generation of new facts or perspectives on a problem. If researchers, inventors, innovators, and explorers take the natural routes of inquiry in their contexts and follow the best-practice procedures in their fields, they are likely to contribute to the forward march of their discipline. By applying prodigious and conscientious effort to well-chosen problems and methods, with adequate or better resources, much persistence, plus whatever lucky circumstances may appear in terms of insight, intuition, ingenuity, serendipity, or chance, a transformative breakthrough may be generated. In fact, history suggests that with this slippery formula, breakthrough and transformation will indeed occur, but when, where, for whom, and with what implication is largely a matter of speculation.

The problem lies just here. Those slippery elements and lucky circumstances represent a sort of learning lottery. This conception of breakthrough learning suggests a recipe of one part established process and one part grace of fortune. Such an explanation is neither satisfying as an explanation for past successes, nor particularly useful as a
guide for future efforts. That guide could make a significant contribution to our future well-being. Root-Bernstein & Root-Bernstein (1999) describe the need:

The complexity, unpredictability, and pace of events in our world, and the severity of global environmental stress, are soaring. If our societies are to manage their affairs and improve their well-being they will need more ingenuity—that is, more ideas for solving their technical and social problems. (p. 1)

Economist Ray Fisman (2011) recently advised American educators to concentrate not on rote learning and standardized achievement, but instead on “promoting free thinking and creativity…[focusing] on generating a few revolutionary ideas to ensure the next iPhone or Facebook is conceived and designed in America” (p. 48) (see also Homer-Dixon, 2002). Yet, who has enough understanding of the process and conditions of breakthrough originality to know by what direction education could aid the generation of those revolutionary ideas?

Though original breakthrough learning, by definition, is not reducible to a dependable formula (nor does the model of breakthrough learning presented here pretend to be such a formula) that fact does not excuse its dismissal as an anomaly. As for other human social processes, the appropriate goal is greater understanding for the sake of some degree of improved practice and outcome, as well as for the satisfaction of gaining insight and new perspectives. It is possible that a deeper and more integrated understanding of the situation may serve as beacon or compass for future projects. We may find through more inquiry into this issue that the picture of the breakthrough learning event is fundamentally different than for incremental original learning, or we may simply develop more insight into the less tangible and predictable aspects of
breakthrough success. In particular, by considering cases of unusually successful breakthrough learning efforts, we may discern key factors of positive deviance (Pascale, Sternin, & Sternin, 2010; Root-Bernstein & Root-Bernstein, 1999) which may serve and shape prospective projects and their outcomes. Michael Howe sets up the problem this way: “The exceptional individual goes further, and may move ahead faster, but always there is a route to be traced” (McDermott, 2007, p. 293), an observation which reflects the context of this dissertation.

Transformative Learning

One of the defining lines of inquiry in adult education in recent years has been transformative learning. Now the paradigm-shifting aspect of breakthrough learning projects calls upon transformational learning theory and related concepts central to both self-directed learning and transformational learning. Mezirow calls transformative learning “the process of effecting change in a frame of reference” (1997, p. 5), which is a way of describing the paradigm changes in physics and cosmology achieved by Einstein. The experience of the transformative learning process both requires and develops autonomy in the learner (Mezirow, 1997). Mezirow says “the process involves transforming frames of reference through critical reflection of assumptions, validating contested beliefs through discourse, taking action on one’s reflective insight, and critically assessing it” (1997, p.11; see also Baumgartner, 2001; Cranton, 1994; Grabov, 1997; Taylor, 1998, 2000, 2008, 2009; & Taylor & Jarecke, 2009).

Pilling-Cormick (1997) suggests that during the self-directed learning activities, like prioritizing and seeking out resources, “individuals do challenge assumptions. They need to reflect on their needs and assumptions as they plan their own learning. If their
assumptions about their learning change, then the process becomes transformative. Transformative and self-directed learning are intertwined…As Cranton (1996, p. 95) claims, ‘Self-directed learning is a foundation of transformative learning,’ and theoretically, each concept builds on the other” (p. 69).

Transformative learning (as well as self-directed learning) is also related to some other important constructs in adult education, which include: (a) critical thinking (logical analysis, reflection, and questioning of assumptions [Brookfield, 1987]); (b) autonomy (freedom of choice and reflection [Candy, 1991; Brock, 2010]); (c) critical incidents (triggers for critical thinking and transformative learning [Cranton, 1994], also called disorienting dilemmas by Mezirow[1991], crucial incidents by Houle [1961], and crises by Kuhn [1962]; (d) lifelong learning cycles (or disorienting dilemmas and developmental stage influences [Houle, 1961; Kegan, 1983; Mezirow, 1991]), and (e) communicative learning (including discourse to support critical thinking, awareness of alternative views, and validation of new perspectives [Habermas, 1984; Mezirow, 1997]).

As richly as the transformative learning theory has been worked and developed since its inception, the focus of transformative learning in adult education today is exclusively on psycho-social transformation as a learning process, or on emancipatory learning as an educational objective. The theory has received a good deal of attention, and has grown from the original focus on individual, personal cognitive perspective transformation to encompass a number of personal and social considerations, from Freirean conscientization to cultural-spiritual approaches to social emancipation and a planetary perspective that seeks to alter humanity’s relationship with the earth (Cranton, 2011; Fisher-Yoshida, Geller, & Schapiro, 2009; O’Sullivan, Morrell, & O’Connor,
Mezirow (2000) acknowledges that transformative learning is a theory in progress.

However, the domain of perspective transformation and revolution in a knowledge domain has not been addressed until now. Whereas Mezirow subtitled his (2000) edited book *Critical Perspectives on a Theory in Progress*, the intention of the breakthrough learning model presented here might be considered a creative perspective on transformative learning—creativity here being the genesis of foundationally new knowledge and capabilities, rather than just adapted ways of being, from a foundation of transformed perspectives in and about a knowledge domain.

Mezirow defines learning as “the process of using a prior interpretation to construe a new or revised interpretation of the meaning of one’s experience as a guide to future action” (2000, p. 5). Creative transformative learning, or original breakthrough learning, re-imagines or overthrows prior interpretations, beliefs, and knowledge structures in a knowledge domain, resulting in significantly new ways to understand and apply the fundamentals of that domain, or in a revolutionary replacement of those fundamentals. Both perspectives on breakthrough learning upset old ideas and beliefs, struggle with what that means in context, and deliver impactful change for future action or navigation within a domain, whether that presents as a profound change in being and relating, or in what humans know or are capable of doing.

A perspective formed during this research, and ultimately a key finding, is that transformative learning is a concept that can and should be extended to knowledge-paradigm shifting transformation. It turns out that the standing model for psycho-social transformation does inform a model of domain knowledge transformation, and for the
most part is extended by the new model presented here. However, much more remains to be said in the next chapter on the process of perspective transformation in the context of original breakthrough learning.

Independent and Self-Directed Learning

Self-directed and independent learning are also key features in this model of breakthrough learning, as well as in the history of human breakthrough and discovery. Einstein, for example, was “largely self-taught in physics,” an independent learner “who had never seen a theoretical physicist (as he later put it), let alone worked with one” (Stachel, 2002/2006, p. 157) at the time he developed his first theory of relativity. Many other significant contributions to human knowledge have come through similar bold, self-directed, efforts. These include Gutenberg’s printing press (1440); the Newtonian theory of gravity, unraveling of light spectra, and conceptualization of calculus (1666); Newcomen’s (1712) and Watt’s (1763) inventions of two generations of the commercial steam engine; Harrison’s invention of a marine clock to determine longitudinal position (1735); Faraday’s discovery of the electromagnetic field (1821), Darwin’s theory of natural selection (1838); Boole’s conception of artificial intelligence (1854); Maxwell’s unification of electricity and magnetism in his formulation of classical electromagnetic theory (1861); Bell’s telephone (1876); Edison’s electric light (1879); the Wrights’ invention of powered flight (1909); Schrödinger’s famous equation for changes in the quantum state (1926), and his later conceptualization of the gene (1944); Watson and Crick’s double helix (1953); Bohr and Heisenberg’s uncertainty principle (1927); Chomsky’s theories of language acquisition (1950’s); Minsky’s foundational contributions to artificial neural networks (1969); Jobs and Wozniac’s personal computer

This roll represents merely a score of breakthroughs, a fractional inventory of largely independent and self-directed breakthrough learning contributions to human civilization. In fact, Johnson (2010) describes nearly 200 “key innovations” from 1400 to 2000 in a fascinating but hardly exhaustive list (it excludes, for example, the Wright brothers’ invention of powered flight), which attributes most of these inventions and discoveries to a single creative and curious individual. Time’s 2010 publication of *100 Ideas That Changed the World* (Lacayo, 2010) similarly brims with tales of independent breakthrough learners. And, in perhaps the finest example, Boorstin (1983), former Librarian of Congress, presents a species-spanning documentary of (mostly scientific and Western) discoverers, naturally bursting with examples of self-directed breakthrough learning. Boorstin followed with tomes crammed with the stories of creative types who have transformed our culture (1992), and philosophical and religious seekers (plus a few statesmen and scientists, including Einstein) whose signal fires have directed us from the beginning (1998).

Even for the creatives and seekers, self-directed breakthrough learning journeys were often important in their stories of learning novel ways of expression and new paradigms of being. In fact, while the mention of original learning, discovery, or knowledge typically evokes examples of leading changes in the physical sciences, medicine, and engineering and technology, artistic invention carries a long history of perspective-shifting invention and imagination. Artists, architect, designers, writers,
filmmakers, and other professionals tagged as creative types work in a mode of novelty-creation, of re-envisioning and reaching toward the perspective shift that will allow them to present work that expresses a new view, challenges old conventions and paradigms, or creates new conventions from a breakdown of the old ways.

A few examples of original contributions at the breakthrough level in artistic fields include the invention of musical notes by Guido of Arezzo (1025), the framework-independent architectural dome invented by Brunelleschi (1436), the opera (Dafne) as introduced by Jacopo Peri (1597), the science fiction novels first instituted by Cyrano de Bergerac with A Voyage to the Moon (1657), the photographically illustrated book (British Algae: Cyanotype Impressions) first introduced by Anna Atkins (1843), Seurat’s (1884) pointillism, the Cubism of Picasso and Braque (1907), electronic music first developed by Lev Theremin by experimenting with motion near antennae (1919), science fiction movies heralded by Lang’s (1926) special-effects rich Metropolis, and Pollock’s (1952) action painting form (Allmusic, n.d.; Ibiblio, n.d.; Jackson-pollock, n.d.; Kavina, n.d.; Morgan, 2011; Organ, 2011; PBS, n.d.; Photography-news, n.d.; Stengel, n.d.; Swanson, n.d.). Such breakthrough learning in artistic domains may not represent knowledge transformation as much as symbolic-perceptual or pragmatic-perceptual revolutions in how we experience meaning at the level of aesthetics, story, musicality, and other provocative means of sharing or generating meaning perspectives amongst ourselves.

The process and experience of coming to these breakthroughs, as will be seen with a closer look at creativity theory in Chapter IV, can be embodied as a self-directed learning project with a breakthrough result, though it may not be perceived in those terms
by the artists. This breakthrough work, by any name, is likely to involve a meaningful, motivating catalyst (which is another way of saying a disorienting experience), a process of critical and imaginative reflection on old and emerging perspectives, a period of intense interaction with the learning problem (in this case the idea and medium of artistic expression) in a mode of insight-provocative attention, and finally an integration of the new perspective in probably startling new creative form.

The history of breakthrough in every domain is rich in these examples of independent individual or partnered learners creatively pursuing a new understanding or expression of meaning in their fields. However, some deny “the image of the lone genius inventing from scratch,” calling it “a romantic fiction” (Hargadon & Sutton, 2001, p. 55). As it happens for that particular quote, Hargadon & Sutton are interested in a business creativity paradigm which is called the innovation factory, and they are specifically discussing invention and innovation in rapid cycles of idea capture and elaboration, resulting in commercially important, but not domain transformative, shifts in products like highly engineered athletic shoes, electric shavers, and surgical scalpels. Giving lie to Hargadon & Sutton’s dismissal of independent inventors, the creator of a famous innovation factory, IDEO, shares the concern of a business writer who had “a dire prediction: ‘Out there in some garage is an entrepreneur who’s forging a bullet with your company’s name on it….You’ve got to out-innovate the innovators’” (Kelly, 2001, p. 3). Even for those who want to dismiss highly self-directed creativity, the phenomenon of independent innovators remains valid and, for some, a threat. The “lone genius inventing from scratch” and the solitary out-of-the-garage innovator remain worthy of study.
Another reference tag for self-directed, independent, or autonomous learning is autodidacticism, or the phenomenon of being self-educated. Candy, a significant contributor to adult education research in self-direction and autodidacticism, refers to this phenomenon as autodidaxy, or “the systematic study of intentional ‘self-education’” that reaches back to Houle’s (1961) work with lifelong learners in the early 1960’s (Candy, 1991, p.158). The notion of self-directed learning goes back far into human history. Candy insists that “it has in fact been a recurrent concern of educators in all ages, in most cultures, and for all levels” (p. xiv). He describes the Roman notion of the teacher’s “trivial” role in passing on the knowledge of the trivium (grammar, rhetoric and logic), a preparation for the more important work of self-education.

Defining self-directed learning is more complex. Brockett and Hiemstra refer to self-direction in learning as a compilation of internal and external aspects they call learner self-direction (“characteristics of the learner”) and self-directed learning (“characteristics of the teaching-learning transaction”), all influenced by “factors within the social context” and characterized by personal responsibility (1991, p. 25). Earlier, Oddi (1987) created a similar distinction between process perspective and personality perspective in self-directed learners.

The personality perspective is important to note since several key aspects of self-directed learning are not accounted for by the process, or instruction mode, perspective. Those aspects include reflection on learning and experience as a key part of learning, inquiry and active discovery as requirements for becoming an autonomous learner, and the prominence of learning through experience over learning through instruction. Ponton, Carr, and Derrick (2004) portray the importance of conative factors, in this case
resourcefulness, initiative, and persistence, on the tendency to be an autonomous learner. Dickinson and Clark (1975) investigated learning orientations and participation in self-education and found that Houle’s (1961) “learning orientation” type of learner was clearly associated with participation, but Houle’s other two types, “goal orientation” and “activity orientation,” were not. Both of these perspectives, process and personality, figure into the present research project, since it covers both the process of learning and also the apparent personality factors and personal (cognitive and affective) experiences related to the various points within the learning process.

Bouchard (1994) describes self-directed learning in terms of three paradigms. The first, the contingency control paradigm, which Bouchard relates to Tough’s (1966, 1971) perspective, says that self-directed learning depends on external forces. Guglielmino’s (2004) work in psychological variables of self-directed learning led to Bouchard’s psychodynamic paradigm. The psychodynamic paradigm depicts self-directed learning as a response to needs, impulses, and innate instincts. Finally, the systemic paradigm considers self-directed learning inseparable from the complex knit of the learner’s past and present life situations and experiences. Spear and Mocker’s (1982) focus on the organizing circumstance led Bouchard to the systemic paradigm.

Bouchard did even more interesting work a few years later (1996a, 1996b). He developed a model that describes five elements of self-directed learning which, he finds, when taken together, result in a reliable model which should render the learner open to autonomous learning. Bouchard’s five elements are: a strongly felt need for self-development, particular self-ascribed values and beliefs; an autodidactic leap; environmental opportunities to learn, and “an unfolding of successive learning objectives
that are linked to the learners’ growing awareness of their professional field” (1996b, p. 14). Important self-ascribed values, characteristics, or beliefs include creativity, optimism, high capacity for learning, and curiosity, and also fear of failure, lack of patience, aversion to authority, rebelliousness, and low discipline.

When the participants described their learning process, they included an “emergent goal structure, a number of specific learning strategies, and the ‘autodidactic leap’” (Bouchard, 1996b, p. 7). This leap happens at the start of the project when the learner takes an action that places him squarely on the path of learning “on their own, often under considerable pressure. This point of no return left the learners virtually flying without a net” (p. 8). One person gave false qualifications in order to get a job, and then had to learn quickly. Another quit a good job to travel in order to “become more knowledgeable about the world” (p. 8). Perhaps his most interesting finding was that, contrary to the assumption that a number of factors must be favorable in order for self-directed learning to occur, self-direction can occur in otherwise adverse circumstances as long as the requirements of his described model are met. He found that self-directed learners are more resilient than expected, and sometimes difficulties serve to strengthen their will to learn and achieve, a finding which echoes Kett’s (1994) description of the “private study and mutual improvement” (p. 449) of voluntary education “under difficulties” (p. 87) which was the predominant context for adult learning for most of American history.

Tough (1971), who was the first to operationalize the concept of self-directed learning for research in the adult education field (Candy, 1991), focused on the self-planned aspect of learning projects that are considered to be self-directed in nature. He
described a highly structured, purposeful form of self-directed learning, or non-formal learning (Shrestha, Wilson, & Singh, 2008). However, other researchers, including Spear and Mocker, have since found evidence that pre-planning of learning may be rare among independent adult learners (Candy, 1991). In fact, Candy is concerned about the tendency of researchers and theorists such as Knowles and Tough to impose templates on the independent learner’s reported experience, an approach that may be more appropriate to the formal education process. Rather than concerning themselves with planning and organization of the learning project, Raya & Fernandez (2002) suggest that self-directed learners more importantly must learn to “recycle themselves constantly” (p. 67) in response to new sources and types of information and other changes in context in the learning project.

Danis & Tremblay (1988) also disputed some assumptions about self-directed learning, including self-planning. They developed a set of descriptors of self-directed learners, 17 of which are easily supported by adult education dogma (e.g. learning controlled by the learner, and learners creating their own rules), and 13 more challenging principles (e.g. learning not tied to developmental stage, learners not consciously planning and assessing their projects, and non-linear learning and problem-solving processes). Wilcox (1997) also disputes models that assume a high degree of organization, describing a zig-zag process for herself, including “getting lost in the middle of learning. I let go of structured attempts at learning and relied heavily on intuition to guide my progress. I continued to learn, but frequently felt isolated and uncertain.... I did not know how to proceed” (p.26). At this stage of loss and confusion, she recognized her situation as a trigger for transformative learning, though she
questioned whether she was “really open to the prospect of self-transformation” (p. 26). She reports this stage of her learning project as “finding courage to continue” (p. 26). This research behind this dissertation asked, how frequent is such a disorienting dilemma experienced as part of major self-directed learning projects (Dirkx, 2001; Mezirow, 2008)? The answer, it turns out, is that disorienting dilemmas, called disorienting experiences in the model presented here, appeared quite frequently, at virtually every key turning point in the project.

Additional debates about self-directed learning have centered on goals, such as personal growth, transformational learning, or emancipatory learning with social action—with no reference to original learning as a goal, except in Cavaliere’s work. Research in self-directed learning has also yielded ideas about process, including linear, interactive, and instructional models. Researchers have also investigated attributes of self-directed learners and the predictability of those characteristics in a learning situation, and the ability to teach or facilitate the development of self-direction in learners, with divergent results (Brockett & Hiemstra, 1991; Merriam & Caffarella, 1999; Nah, 1999). Definitions of independent learning are also debated. Some critics, including Usiskin (2000), refuse to credit learners who have formal education with independent learning status as well. Usiskin suggests that talented autodidacts would be more successful and would contribute more by paying more attention to formal schooling than to self-defined learning paths. However, in taking this perspective he discredits generations of exceptional learners who have made significant learning contributions through their autonomous learning projects, not infrequently, as in the cases of Microsoft founder Bill
Gates and Facebook creator Mark Zuckerberg, at the expense of finishing their formal education.

Motivation to pursue self-directed learning is an additional avenue of inquiry. Osborne (1997) connects a lack of self-discipline with the motivation to pursue self-education, and also suggests that unique problem solving approaches and distinctive originality may be related to individualistic and independent education—a condition certainly found in Einstein’s case. Rodia (2001) describes the choices of an autodidact learner as driven by her desire for a great variety of learning experiences and contributions. Aspects of her process, including writing to learn, explaining to others in order to learn, talking with others about their learning projects, and walking regularly to shift the mind and body away from focused study all mirror’s Einstein’s choices and instincts as a self-directed learner. Boshier (2002) portrays independently-educated individuals as motivated by suspicion of authority and lack of attraction to higher educational institutions. The suspicion of authority, at least, echoes some of Einstein’s own motivations for independent learning.

Hailey (1988) describes her autodidactic leap as a response to formal education’s control of her educational destiny, as well as the way in which the demands of formal education left no time or space for her to pursue her own learning directions. Autodidaxy became a necessary luxury for her, and she took comfort in classical examples of self-taught learners who exhibited a certain autodidactic nerve. Hailey fashioned herself after Tolstoy, who entered college early but left quickly to manage his own education; Flaubert, who, after failing his law examinations, developed himself in the field of literature, and Milton, who is often credited with having read everything ever published.
Henry Adams (1918/1961) likewise considered his opportunity for extensive self-education a luxury. As “a fourth child,” he said, he had “the strength of his weakness. Being of no great value, he may throw himself away [in learning] if he likes, and never be missed” (p. 70).

While Einstein chafed as Hailey did at the constraints and demands of formal education, unlike Hailey’s and Adams’s desires for a broad and meandering self-education, he pursued his self-directed learning with a strong focus that might be described as an obsession to answer questions that burned in his mind. To some degree, this focus and sense of mission accounts for his persistent giving back to the learning pool through his original learning contributions, whereas Hailey’s and Adams’s lasting public contributions were their published accounts of their learning experiences as self-directed learners.

In spite of the impressive breakthrough-and-discovery résumé of the independent self-directed learner, the circles of inquiry around adult self-directed learning and creative breakthrough learning rarely overlap. The extraordinary impact of such learning projects must be weighed against the temptation to underrate their potential significance by means of their exceptionality. The tradition of self-directed original learners’ societal contributions runs deep, and might be helped to continue even more robustly.

Certainly, there is some logic to the scarcity of adult education research into exceptional original learning projects. Cavaliere (1988) indicates that “attempting to gain original knowledge and insight” (p. 81) is atypical in an independent adult learning project, based on Tough’s (1979) assertion that adult independent learning projects are usually about gaining established knowledge. The relevance and importance of
embracing original breakthrough learning as a province of adult education could be minimized with the argument that the smallest fraction of adult learners will be successful paradigm shifters. Yet, however atypical the desire for original learning may be, it is foundational to human progress and survival.

Self-directed learning, it should be noted, is a theory frequently applied to childhood education (Livingston, 2007), and with increasing frequency so is transformative learning theory applied to childhood education (Cahill & Bulanda, 2009; Mooney & Anderson, 2011; Holistic Education Network of Tasmania, 2011). Though these theories gained popularity in the context of adult education, they are adapted to reflect both childhood and adult situations, or, in the case of Einstein and some other breakthrough learners, the learning situation bridges childhood and adulthood. Thus, self-directed and transformative learning are not, as initially supposed, uniquely adult-oriented explanations of learning and education, a situation reflected in Einstein’s learning journey and its important roots and activity throughout his childhood and youth.

Yet, while not presently an important part of the adult education literature, original learning and breakthrough learning, with few exceptions, are notably adult achievements. While some independent learning projects, like Einstein’s early light wave investigations that led him ultimately to theories of relativity, have important bases in childhood and youth, and the learning project spans the full lifetime, the productive output of such projects usually depends on the attainment of adulthood and more mature cognitive processes and foci, as well as a growing store of life and learning experiences. Thus, while breakthrough learning theory matters to learners and educators at any level, the flowering and fruition of such learning projects in adulthood suggests a special
application to adult education, and a particularly relevant link to other theories of adult education.

While self-direction or autonomy is one of the two conditions on which the model presented in this chapter relies, the other condition remains to be addressed—a learning environment that is adequately supportive or at least not overwhelmingly obstructive to the learner’s self-motivated purposes and process. Merriam (2008a) tells us that the contexts and conditions of adult learning are now a key pattern of focus for adult learning theory. In addition to the hallmark theories of self-directed and transformative learning, what insight does adult learning theory offer about the conditions under which adults go about self-directed original learning endeavors?

Learning Environment

A key theory of adult learning which pertains to the self-directed original learning phenomenon by way of the learning environment is andragogy, particularly because it contrasts directly with the learning environments in which Einstein struggled and suffered, and which he loathed for a lifetime on behalf of all learners of every age. Andragogy, a set of principles highlighting learner experience and preference for self-direction in the learning environment, is described by the six core principles of need to know; self-direction; learner experience; readiness to learn; problem-centric approaches to learning, and intrinsic motivation (Knowles, Horton, & Swanson, 1998, 2005).

Rachal’s 2002 description of “an idealized implementation of andragogy…allowed by a truly volunteer adult learner motivated to pursue objectives of her or his own choosing, unconstrained by grades, prescriptive content, or other external requirements” (p. 219) is a description of Einstein’s approach to his learning work, and
by contrast highlights most of what he despised in his formal learning experience (Beck & Havas, 1987; Einstein, 1954a; Einstein, 1949/1979; Stachel et al., 1987). The description is so apt that it suggests that idealized andragogy might especially, or only, apply to self-directed informal learning—paradoxically, if that were to be the case, as so many teacher-mediated adult learning situations have been carefully designed to achieve andragogical purity to the greatest possible extent in the classroom.

In the case of independent, self-directed learning, andragogy’s tag line, “the art and science of helping adults learn,” (Knowles, Horton, & Swanson, 2005, p. 61) needs to cover a more unusual form in which the learner is natively at the helm of the project, rather than just empowered by a permissive pedagogy to take back, probably tentatively, some of the ownership that traditionally rests in the teacher or institution. A transactional shift to learner-directedness is what andragogy’s adherents attempt to create within traditional learning situations (Knowles, Holton, & Swanson, 1998, 2005), yet it proceeds quite naturally from independent learning situations. Is it possible that any formal learning circumstance is itself the beginning of “paradigm devolution” (Rachal, 2002) for andragogy?

While Einstein, as a child, chafed against any formal instruction that did not fit his agenda for learning and exploration, he was deeply affected by the learning conditions in all of his schools. His early schooling, analogous to our elementary schools, was terribly authoritarian, with physical punishment for incorrect or slow answers, and rote learning the featured teaching strategy. High school was not much improvement, and he left school at sixteen to try to enter college early. Failing that attempt, he enrolled in a progressive Swiss technical high school to finish his preparation for college, and for once
seemed to bloom as a learner with the help of his learning environment rather than instead of it.

In fact, Einstein’s earlier schooling experiences seemed to cause him to retrench his determination to be an autonomous learner, and his self-directed learning efforts grew the longer he was forced to endure his barely tolerable school environment. However, it is not hard to imagine that a more severe school environment, or a less supportive home environment, or a less self-willed child, could have resulted in a complete quashing of the spark of a breakthrough learning project. While Einstein and his learning project survived the school system, including college which was less authoritarian but still more restrictive and tradition-bound than Einstein and his learning project could bear on a daily basis (and so he skipped school to study on his own much of the time), Einstein lobbied throughout his mature writings and addresses for a form of education that would leave creativity and the independent learning spark alive. It is easy to see that he did not escape without wounds and resentment.

Certainly andragogy was not intended to address the situation of childhood education. However, this researcher takes the view of the learner, in this case Einstein, as a whole, cradle-to-grave learner, and not one who is profoundly different as a learner or in his learning environment requirements at six, sixteen, twenty-six, or sixty. The precepts underlying andragogy address, for the most part, concerns that Einstein felt throughout his exposure to formal learning environments and long after he had separated from them as either student or teacher. This is worth noting when considering any formal learning environment that may intersect with an independently-minded, creative learner, of any age, with a self-directed learning project on his mind.
Though Einstein, like other breakthrough learners, spent a lot of his learning opportunities in a formal learning environment, happily and productively or not, the bulk of Einstein’s happy and productive learning occurred in less formal environments. He spent much of his time studying on his own at home or in a library. Later, in college, and after graduation, and as a young worker, he could be found in homes and coffee shops with like-minded learners. As a self-employed learner, as it were, whether or not he had a day job to pay the bills, these locales for learning circles and intellectual discourse were important elements in his mobile breakthrough-learner designed workplace.

Emerging theories of workplace learning are informative, even if, by definition, they would seem not to apply to independent learning. The newer focus of workplace learning theory is on informal learning in the workplace, edging away from learning as necessarily the attainment of established knowledge, and looking instead at embedded learning; learning communities; the complexity theory of interdependent learners, and cooperative learning from mingled experiences and relationships. Workplace learning theory also embraces the everyday practice of conversation and exchange of ideas, particularly looking at “expanding human possibilities for flexible and creative action in contexts of work” (Fenwick, 2008, p. 19; see also Dawson, 2005). Work in each of these areas shows promise for considerations of how independent but professional learners come together to converse, share resources, briefly collaborate, or provide other practical, intellectual, or social supports to each other’s work. Coffee-house learning shared by independent, creative learner-workers was a valid and important part of a learning project in Einstein’s day, as it remains today.
While Einstein navigated a number of learning environments over the course of his breakthrough learning projects, as a student, a self-proclaimed bohemian, a teacher, and finally as an intellectual free agent hosted by an academic establishment (Princeton), the informal and nonformal learning situations seem to have been most important in developing his identity as a competent independent learner. This helped when he got contrary feedback from school. And his non-formal learning environments also developed him into a self-identified scientist even as the scientific world refused him entry (Einstein, 1987; Hull & Greeno, 2007; Winteler-Einstein, 1987).

For example, the Olympia Academy, a group Einstein formed as a young man with two friends for discussion and collaborative learning in physics and philosophy, provided a social interaction with the learning that may be particularly important for independent and self-directed learners (Duensing, 2007), and introduced him to resources and ideas he was rather desperate for in his learning environment, for much of his employment-seeking correspondence cited his desire and need to find work in a situation that provided resources for his continued learning in science. When such a situation never materialized, he had to find his own resource-rich environment to support his learning project.

Understanding the context of the people and resources associated with a major self-directed learning project is important to understanding the project itself and the process of achievement (Ash & Wells, 2007). Resources, of course, are critical to the independent learner. As several significant scientists of the next generation learned from and related to Einstein through his writings (Heisenberg, 1983), Einstein encountered many of his teachers, mentors, and inspirations in books and articles, first by science
popularizers and then by experts. He sometimes corresponded with these authors, effecting more literal encounters with them, and corresponded with friends and colleagues about his research, a practice which may have aided him in formulating his reasoning verbally and in trying out or arriving at conclusions (Howard & Barton, 1986). Depending heavily on documentary resources in his autodidactic learning missions and the research for his theories, he made good use of the “invitational environment” of libraries (Carr, 1985, p. 51) and also borrowed from friends or colleagues, or enjoyed the gift of resource books from family or friends.

McDermott (2007) notes that in any apparently individual achievement “there are always prior developments, always others involved. Behind every lone inventor, there are others: helpful and essential, but uncelebrated and hidden” (p. 293). A guiding principle for the present research can be found in McDermott’s comment below, easily substituting Einstein for Pasteur:

To describe [Pasteur] without an account of the game board and the moves of other players would hide what is crucial. It would be unfair to Pasteur to ignore the ingenuity he spent organizing others. Pasteur did not do what he did because he was a genius. He is distorted by a learning theory that simply names him and hides his struggles. (p. 297)

While independent, original learning is the subject of this study of Einstein’s learning work, the intention is not to display the learning as isolated or out of a larger context of community, culture, and resources which shape the largely informal environments in which independent breakthrough learners do their work. In fact, a network of learning interaction support must attend every breakthrough learner, no matter
how independent. Network theory describes the interactions and organization of subgroups within the web of social ties and communication system, illustrating, in this case, the use of human and informational resources and relationships for the benefit of the independent learning project (Barab, Hay, & Yamagata-Lynch, 2001; Barabási, 2002; Cavaliere, 1988; Reid & Smith, 2009; Srestha & Singh, 2008; Wade, 2005; Wiuf, Brameier, Hagberg, & Stumpf, 2006). Silberman-Keller (2007) calls networks “a metaphor for the structure of nonformal education that operates in accordance with nonformal pedagogy” (p. 256), but it is a more literal view of the structure of much independent learning, which is not achieved in total isolation but requires varying degrees of interaction and resource retrieval in order to complete the many stages of a complex learning project.

Viewing independent learning through the lens of network theory supports the growing concept of self-directed learning as part of a social context rather than a purely isolated endeavor (Brockett & Hiemstra, 1991; Candy, 1991; Cavaliere, 1988). Barabási describes individual success within networks in terms of individual, or nodal, fitness within the environment of a network (p. 95), and in fact found that one of Einstein’s theories of subatomic behavior, called Bose-Einstein condensation, provides a stunningly accurate model of the competitive behavior of complex networks. While Cavaliere’s work on the Wright brothers’ breakthrough learning featured an explicit model of networked learning resources and worked with the concept of the information power base on the success of learning projects (Cavaliere, 1988, 1992), this model of Einstein’s learning journey discusses his use of a learning network more implicitly, though the importance of a learning network is less important to his work.
Motivation

Research into learning motivation is another area of adult education which informs the model of independent breakthrough learning. Motivation appears first and primarily in the model in the first component of the four-stage process, a disorienting experience in a meaningful context. It also appears throughout the model, as the condition of self-direction or autonomy may include inherent motivators for the learning project, as do other situations with the learning environment, and experiences during the periods of critical reflection and intense interaction with the learning project. For example, motivation is often enhanced by interaction, justification, and recognition coming from colleagues and others in the sphere of learning, as Einstein described to his colleague (Born, 2005), reporting that he had “a feeling of happiness at being completely understood and acknowledged by one of the best of my colleagues” (p. 3).

Motivation seems to be multi-layered, and is a broad topic, even when focused singularly on self-directed breakthrough learning, and it certainly overlaps with theoretical domains besides adult education. Nevertheless, since it is an important part of the model, it deserves some independent treatment.

Adult learning projects have complex causes and objectives. Some attribute adult learning motivations to developmental tasks (Havinghurst, 1972), a desire for adventure (Pietersen, 2002), or the intention to enable personal or spiritual growth or connection (Tisdell, 2008). Einstein’s experience actually reflects each of these perspectives. As he struggled with identity, purpose and meaning in youth and found answers in scientific exploration, as he was motivated by a kind of adventurous spirit he often referred to in awed terms of wonder or holy curiosity, and as he was strongly oriented throughout his
career toward a desire to be connected to the divine through an understanding of natural laws, his meaning layers served as engine and guide-light throughout his work. Without these motivators, it is doubtful that these breakthroughs would have been brought into the world by Einstein, so persistently significant were they at every stage in his work.

Sometimes motivation for a lifetime of independent, original learning is felt as a calling, as for Davies (2004, p. 53) who “was born to be a theoretical physicist.” Many others describe their drive as coming from doing what they love, or doing something that makes an important difference (Dyson, 2004). While Einstein’s purpose could be described in light of any of those categories, considering the language he frequently used to describe his learning projects, he was driven by the mysterious; by an “innocent, naive sense of wonder” (Overbye, 2006, p. 327); a “childlike sense of marvel” (Isaacson, 2007, p. 548), and, famously, a desire to know a creative God (Jammer, 2005; Malin, 2001/2006): “When I am judging a theory…I ask myself whether, if I were God, I would have arranged the world in such a way” (Isaacson, p. 551). Others have described Einstein’s motivations in terms of a philosophical mindset (Howard, 2006); his nature as a dreamer (Glass, 2005); a fierce desire to solve the problems his mind set for him (Magueijo, 2003/2006), and by a sensitivity to aesthetics, or the beauty and balance in the universe (Hoffman, 1983; Margenau, 1970; Weinberg, 2005/2006)—all motivations described by a number of scientific thinkers, not just Einstein (Brockman, 2004).

Einstein (2004/1934) gave a further, more intimate view of his drive to pursue his learning projects:

One of the strongest motives that lead men to art and science is escape from everyday life with its painful crudity and hopeless dreariness, from the fetters of
one’s own ever shifting desires. A finely tempered nature longs to escape from personal life into the world of objective perception and thought; this desire may be compared with the townsman’s irresistible longing to escape from his noisy, cramped surroundings into the silence of high mountains, where the eye ranges freely through the still, pure air and fondly traces out the restful contours apparently built for eternity. With this negative motive there goes a personal one. Man tries to make for himself in the fashion that suits him best a simplified and intelligible picture of the world; he then tries to some extent to substitute this cosmos of his for the world of experience, and thus to overcome it. This is what the painter, the poet, the speculative philosopher and the natural scientist do, each in his own fashion. He makes this cosmos and its construction the pivot of his emotional life, in order to find in this way the peace and security which he cannot find in the narrow whirlpool of personal experience. (p. 2)

A persistent finding in motivation literature is that, while some adult learning theories feature commitment or persistence in learning as a factor of learning success, they don’t usually explain that such persistence likely must come from a strong, positive, intrinsic source leading to a relentless, seemingly organic engagement with the work. This was true for Einstein’s strong orientation to marvel and wonder, and also true for his deep enjoyment of the work, something he called “love and devotion towards men and towards objective things” (Dukas & Hoffman, 1979, p. 46). This dedication is often found in successful independent learners even while that devotion often means that one’s work is “the meaning of life…the core axis of everything that counts” (Dawson, 2005, p. 34), and thus so defining and encompassing that relationships and other features of life
suffer in consequence (Schulmann, 2005). When novelist John Irving, who invested exceptionally long hours in his writing even after achieving fame and fortune, was asked why he continued to drive himself so hard, he answered by weaving together intrinsic motivation and play, another catalyst for independent breakthrough learning: “The unspoken factor is love. The reason I work so hard at my writing is that it’s not work for me” (Collins & Amabile, 1999, p. 297).

Calle (2008), a research physicist and biographer of Einstein’s science, sums up the essence of Einstein’s personal orientation toward his learning work, emphasizing the “core axis” which his work was in his life. In a rhetorical question and answer session with Einstein, Calle asks, “Is your mind ever far from your science?” Calle answers in Einstein’s voice, “Not often. Music is perhaps the exception. I feel deeply the music I play or listen to. But seeking to discover nature’s secrets is exhilarating, and this joyous activity constantly fills my mind. To be a scientist is to remain a child all through one’s life, always marveling at the discovery of another wonderful phenomenon” (p. 136).

This discovery work—the process, the journey, the core action level—is the main focus of Chapter III. The third component of the breakthrough process model, interaction with the learning problem (coming after a disorienting, catalyzing experience, and after or integrated with critical reflection on perspectives and meaning), comprises patterns of action and thought, as well as a particular quality of attention. These will be explored in detail in the coming chapter, after which a fourth chapter attends to a comparative review of breakthrough process models, until finally in Chapter V and following, more specific views of Einstein’s learning patterns and the storyline of Einstein’s journey unfold.
CHAPTER III
ATTENTION, INSIGHT, AND INTEGRATION IN BREAKTHROUGH LEARNING

If A is success in life, A = x + y + z. Work is x, play is y, and z is keeping your mouth shut. – Einstein

An Extended Typology of Transformative Learning

The bulk of the action in breakthrough learning occurs in the third and final stages, persistent interaction with the learning problem (this is where significant creative insights are likely to occur, though they may occur at any stage), and integration of the learning with validation and actualization activities. Whereas the previous chapter described the general model of breakthrough learning generated by grounded theory analysis of the Einstein learning project, and highlighted the first two stages, disorienting experience and critical reflection, this chapter completes the review of the model while expanding on the extension of the transformative learning model.

The interaction stage is all about attention to the learning problem, as well as qualities of attention which facilitate finding solutions, creating solutions, or experiencing exceptionally creative insights and breakthroughs. Attention is the necessary labor (or play, depending on the attention mode engaged) that must occur before most breakthroughs, and before any complex learning problem is brought to conclusion.

Gallagher (2009) underscores the significance of attention:

When we imagine Einstein coming up with E=MC² or Michelangelo sketching the design for the Sistine ceiling, we envision these protean creators lost in rapt attention to their great breakthroughs. Such Ahas!, however, are invariably
preceded by long periods of steady concentration on a subject…punctuated by spells of “incubation,” when the mind’s searchlight seemingly shifts elsewhere. After spending years thinking about the individual’s rights and studying the views of the English philosopher John Locke…Thomas Jefferson could “dash off” the revolutionary Declaration of Independence in a matter of days. (p. 134)

The quality of attention matters as well. Gallagher (2009) relates the comments of one artist describing a state of flow:

If she’s working well, [she] is aware of paying rapt attention that’s “really different” from her everyday experience: “When the art is coming, everything else just disappears. All of my other responsibilities fall away. There’s no pressure….I’m not tired. There’s a lot of freedom in that kind of concentration.” (p. 135)

But first, to understand the work and play of attention at this problem-interacting stage, it is necessary to first clarify to what purpose the attention is being paid. This question may be answered in one way by beginning with an array of the functions which guide transformative learning. The extended typology of transformative learning, seen in Table 2, is a view of the impact of bringing non-personal, or field-transformative, breakthrough learning into a conceptual framework with the familiar domain of personal transformative learning. After considering breakthrough learning within a family of transformative learning processes, this chapter examines the implications of scale and completion in breakthrough learning (the discussion of which goes to the heart of the attention and insight elements of the interaction stage), as well as the promise of actualization in the integration stage. Finally, the notion of transformative attention as a
quality or pathway of attention is developed. This is a critical notion since it implies the potential of experiencing the aahs, eurekas, and sighs of relief that are the promise of illumination and conceptual breakthrough in a breakthrough learning project.

Table 2

*Extended Typology of Domain Transformative (or Breakthrough) Learning*

<table>
<thead>
<tr>
<th>Function</th>
<th>Focus</th>
<th>Learning Journey</th>
<th>Perspective Transformation</th>
<th>Breakthrough (examples)</th>
<th>Theorists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Being</td>
<td>Personally transformative</td>
<td>Inner / Personal</td>
<td>Psychological, Socio-cultural, Spiritual</td>
<td>Individuation, Psycho-developmental stage transition, Spiritual awareness</td>
<td>Mezirow, Boyd &amp; Myers, Cranton, Dirx, Elias, Fisher-Yoshida, Geller, Kegan, King, Schapiro, Taylor, O’Sullivan</td>
</tr>
<tr>
<td>Relating</td>
<td>Personally or socio-culturally transformative</td>
<td>Intra / Personal</td>
<td>Psychological, Socio-cultural, Spiritual</td>
<td>Conscientization, Social narrative transformative</td>
<td>(Same as for Being, above)</td>
</tr>
<tr>
<td>Doing</td>
<td>Externally transformative</td>
<td>Outer / Non-personal</td>
<td>Techno-cultural, Creative-cultural</td>
<td>Invention</td>
<td>Related theorists include: Cavaliere (for self-directed breakthrough learning); Kuhn (for scientific revolution); Christensen (for disruptive technology); Csikszentmihaly (for creativity)</td>
</tr>
<tr>
<td>Knowing</td>
<td>Externally transformative</td>
<td>Outer / Non-personal</td>
<td>Philosophical, Cosmological</td>
<td>Discovery</td>
<td>(Same as for Doing, above)</td>
</tr>
</tbody>
</table>
In this extended typology of transformative learning, the learning work which may result in breakthrough, or perspective transformation, can be found in four functions: being, relating, doing, and knowing. The functions of being and relating are the focus of personal transformative learning as described by Mezirow (1991) and transformative learning theorists. The functions of doing and knowing describe the non-personal breakthrough, or transformative, learning that may occur in the process of original learning. Certainly these functions overlap in human experience and all types of learning projects, such that doing and knowing functions are implicit in personal types of transformative learning, and being and relating functions will also play a role in non-personal breakthrough learning in the process of original learning. Despite these overlaps, the distinctions describe a core focus, or area of impact, for each of four types of breakthrough.

The being function naturally relates to personal perspective transformation, and describes an inner journey of challenging and changing perspectives. In Mezirow’s presentation of transformative learning, these changes were most likely to relate to psychological processes like individuation, but they may also refer to psycho-developmental stage transitions, changes in spiritual awareness, or other changes in the being and resulting behaviors of the individual. The relating function is closely aligned to the being function, and describes the more socially emancipatory contexts of transformative learning emphasized in recent years. While this is also a personal learning journey, it is more intra-personal in focus than the decidedly internal focus of individual psychological transformation. Breakthrough types for the relating function include
conscientization, social narrative transformation, and other consciousness-raising, socially emancipatory aims.

The doing and knowing functions share an externally transformative focus, and feature a learning journey that is trained on non-personal learning aims outside the learner, however personally impactful and closely held that learning project may be to the learner. The difference is in the relevance of the learning project to other people. Is the learning breakthrough contributing more to human capacity to do, to act and effect? Or is the impact more significantly on changing the knowledge base in a domain?

Despite the necessary overhangs and intersections between knowing and doing, the angle of impact is generally clear. The creation of human flight transformed human capacity in transportation, and as a result also had major impacts on commerce, communication, culture, and other aspects of human life. The development of the relativity theories revolutionized what we know about how the universe works, and despite the numerous practical, doing-function implications of this knowledge, it is fundamentally a knowledge transformation more than an action-capacity transformation. We even have different names for these kinds of breakthrough: invention, primarily for the doing domain, and discovery, primarily for the knowledge domain. (Of course other terms apply, and invention and discovery are sometimes used interchangeably, creativity being the messy business that it is).

The locus of perspective transformation for the doing and knowing functions can be any field of human endeavor or understanding. While invention often involves a techno-cultural breakthrough, including revolutionary inventions and disruptive innovations in medicine, computing technology, transportation, communication systems,
agriculture, and the like, it may take place in any field. Discovery is generally considered
a scientific or technical endeavor as well, but this is a limiting perspective as discovery
also may occur in any field. Invention and discovery are often closely related, as
invention often opens doors to new discovery, as when van Leeuwenhoek (1632-1723)
invented new methods for constructing microscope lenses (a trade secret he fiercely
protected), allowing him also to become the father of microbiology, making key
discoveries including bacteria, cell vacuoles, and spermatozoa (Boorstin, 1983).
Breakthrough learning, with its inherent and resulting perspective transformations, also
happens in creative-cultural domains like art, design, architecture, music, or literature, or
in highly conceptual arenas like philosophy or cosmology, or in any field of knowing or
doing.

While Mezirow (1991) and his followers did not actually apply his model of
transformative learning to technical, or extra-personal, contexts of breakthrough and
transformation, his explication of his transformative learning theory refers to different
types of meaning perspectives (psychological, sociolinguistic, and epistemic), and three
domains of learning (instrumental, communicative, and emancipatory). Cranton (1994)
works with these in matrix form to present a typology view of Mezirow’s theory of
personal transformative learning. However, her matrix does not seem to allow for a view
of non-personal, field-transformative breakthrough learning. Figure 5, shown below,
builds on inherently non-personal aspects of Mezirow’s learning domains and meaning
perspectives, as well as on the distinction of transmissional (teacher-to-student
instruction) and transactional (facilitated experiential) learning described by Miller &
Seller (1990) as distinct from transformative learning, to indicate how these concepts support the phenomenon of original breakthrough learning in a non-personal context.

Figure 5. Technical domain learning in the knowing and doing functions

In Mezirow’s theory, and Cranton’s derived matrix, the meaning perspectives mostly relate in one way or another to the personal (though not necessarily individual) application. However, the epistemic perspective carries the potential of extension to non-personal transformative learning. In the traditional personal or social application of the theory, though, Cranton illuminates the intended use of the epistemic domain by proposing domain-relevant questions like “What knowledge do I have?” and “Why do I need/not need this knowledge?” for reflection in this arena (1994, p. 51). She does not ask “What knowledge is lacking (in the world), how could I discover or create it, and what difference would that make for myself or others?” Her questions, in the personal and social tradition, naturally are about questioning knowledge that has been acquired,
not about creating or discovering new knowledge as a result of a perspective-transformative learning process.

Mezirow’s three domains of learning (instrumental, communicative, and emancipatory) also seem to suggest a route to non-personal breakthrough, but neither he, nor Cranton, nor other transformative learning theorists embrace that possibility. Instrumental learning involves learning through task-oriented problem solving. Communicative learning refers to the experience of interacting with other people to share, construct, or validate meaning. Emancipatory learning is the work of overcoming assumptions that unnecessarily limit our options. (Cranton, 1994, emphasizes that emancipatory learning is considered both a learning domain and a process which can apply transformatively to any of the meaning perspectives.) Though, on the face of it, any of these domains and processes could be construed to apply to non-personal knowledge-domain transformation, that application has apparently not occurred until now.

Pathways to Breakthrough Learning

Breakthrough learning of all sorts may follow diverse pathways to transformation. The common model of inner or intra-personal transformative learning can be viewed as a relatively straightforward trail, though steps may be overlapping, or rearranged at points, or recursive. This pathway moves from disorienting experience through critical reflection, then on to various actions of interaction and integration with the change problem (for Mezirow these steps would be centered in dialogue, practice, feedback, and verification with other people).

Einstein followed this path at times, as when he shifted from seeing himself as alone and above a sea of non-intellectual “Philistines” (except for his science-student
girlfriend) after college, looking for opportunities to make a living by teaching others what he knew. When being interviewed for a math tutoring position for a young man, he experienced a perspective shift about the expected roles of teacher and student. This young man wanted to be a learner, and Einstein wanted to be a teacher. But Einstein realized that interacting with this thoughtful man triggered the learner in himself. He then saw they could be teachers and learners together, meeting both of their needs (except Einstein’s financial one) better than in their original idea about how they should interact. And thus the Olympia Academy was born, as was Einstein’s mode of challenging interaction with students, looking for learning inside the room and not just in the transmission to students that was occurring in his lectures.

Figure 6. Pathways to breakthrough learning.

Einstein also exemplifies variations on this straightforward path (see Figure 6). One of these variations is the cumulative perspective transformation, in which
revisiting a topic over time creates added or extended perspective transformations. For example, he came to reject the ether as a construct for explaining the propagation of light in space. And, as a result of working with Maxwell’s theory of electrodynamics, he came to see Newtonian classical mechanics as an incomplete paradigm for physical phenomena. Then he realized that light didn’t always act like a wave, as generally understood. Later he came to understand that light emission theories didn’t fully account for light’s behavior either, and so he came to see light in a revolutionary new way, as a quantum phenomena, and he integrated this understanding by publishing a paper in early 1905, before his relativity breakthrough. Integration was extended as empirical evidence mounted for his theory, and as he received the Nobel prize for the theory many years later. While this is a somewhat simplistic and certainly incomplete view of the full set of perspective shifts and learning project plot twists toward Einstein’s quantum theory of light, it illustrates the cumulative nature of perspective transformation in breakthrough learning, each perspective shift reaching a level of integration on its own while being added to, and triggering more of, the wealth of knowledge-transformative learning that was occurring in Einstein’s learning project.

The cumulative perspective transformation is closely related to a nested perspective transformation, in which multiple perspective transformations are triggered in a recursive cycle before reaching an integration stage. When he first heard and read of his colleague and former teacher Minkowski’s mathematical take on space-time, effectively an extending and clarifying perspective on Einstein’s special theory of relativity, he had little use for Minkowski’s ideas on the four dimensional flat geometry of relativity. But then came a series of disorienting perspective shifts. His efforts to extend special
relativity his way were not working and he needed new ideas. Then he heard colleague
Max Born’s ideas about how rigid bodies would move in space in view of the special
theory and found both great potential and troubling paradoxes in Born’s ideas when he
related them to his questions about gravitation. Finally, he found himself with his nose
buried in Minkowski’s work, seriously studying in order to understand it and to imagine
how it might apply, in a transforming reformulation, to his desire to extend special
relativity theory. He saw that Minkowski’s work also could suggest ways to make sense
of Born’s ideas about motion in conditions of relativity, thus providing a working
perspective for reformulating gravitation as a relativity phenomenon. Perspective
transformations added to and played off of each other in an embedded fashion, without
yet achieving integration at the individual perspective level. These incomplete iterations
of perspective shifts kept Einstein on a fruitful path toward actualized solutions.

A fourth pathway to, or through, perspective transformation is the multi-
dimensional perspective transformation. In this variation, perspective transformations at
the personal (inner or intra-personal) level overlap with or have an influential relationship
with non-personal, or knowledge domain, project-related perspective transformations.
One example of the multi-dimensional perspective transformation in Einstein’s learning
journey is exemplified in his path to a life purpose in science, which occurred in
childhood, though there are other examples of multi-dimensional perspective
transformation throughout his career. Einstein was given a compass to play with at age
four, resulting in a perspective transformation process mostly of the technical, non-
personal sort. He went from unawareness of hidden forces controlling the physical world,
to a new vision of a profoundly mysterious, yet knowable, power behind everything.
Back in the personal dimension, Einstein experienced the disorienting experience of learning to navigate the world on his own by being sent out to find his own way around the Munich neighborhood at age four or five (observed, unseen, for a time by his parents). He came to see himself as a competent navigator and self-reliant problem solver, acting independently in the world with the blessing of authority (his parents). Then he went to school and learned that authority does not actually encourage self-directed exploration, navigation, problem-solving, meaning-making, creativity, and discovery. Thus disoriented and perspectively challenged, young Einstein created a new understanding of himself as a learner operating from a defensive and oppositional stance to mainstream experience in order to maintain some identity and freedoms as a naturally autonomous learner with a rich learning agenda of his own.

Also in the personal domain, Einstein underwent a series of perspective transformations as he came to see most people’s purpose and direction as meaningless and futile. He than embraced religion (in an irreligious home) as a perspective transformation and a way out of that futility. Later, he experienced wrenching disillusionment with religion and replaced it with a meaning-rich commitment to science and free thinking. At the same time, he was undergoing further perspective transformations in the knowledge-domain dimension as his interactions with a new mentor (the family friend Talmey) revealed the natural sciences and philosophy as entirely new ways of understanding the workings and meaning of experiences in the world.

This multi-dimensional jumble of perspective transformations (which also, when examined more closely and in light of other perspective development and transformation
not mentioned here, represents a series of cumulative and nested perspective transformations) is a section of a web of meaning perspective transformations that brought Einstein not only to a life of science, but of knowledge creation and revolutionary perspective breakthrough rarely equaled in his field. While these perspective transformations alone do not explain the scale or method of his breakthrough learning, they contribute a lens through which they begin to make more sense, especially when considering the deepening web of perspective transformation, in both dimensions, that carried him along a complex learning journey toward the most complete understanding of relative motion and gravitation that has been conceived to date.

It is also worth noting, not coincidentally, that these perspective transformations occurred well before adulthood. This is not, it is posited, a reflection on early evidence of a markedly superior intelligence or maturity, neither of which was convincingly apparent in his childhood. Rather it suggests that the job of understanding the paths and motivations of the independent breakthrough learner includes considering the learner as a being who did not materialize fully formed as an adult learner, but who has been attending to learning problems and perspective transformations all his life.

The opportunity to acquire many hours of deep practice (Coyle, 2009) with a concept, a capability, or a knowledge domain is a benefit of having the imagination captured early in life. This head start also allows the learner to experience early challenges to meanings and perspectives in this context, which may give the learner an advantage in mastery, performance, contribution, and potentially breakthrough learning in that domain. Because such a commitment to an area of knowledge or practice is a highly personal undertaking, it seems likely that richly interwoven experiences of
perspective transformations, beginning relatively early in life, play a part in the outstanding results of long hours of deep practice and exploration within a particular field.

Degree and Completeness in Breakthrough learning

The case of Einstein’s learning journey also provides some insights into transformative learning by absolute standards or by degree, and into transformative learning occurring within a scale and range of completion and integration. Mezirow (1991) and many other theorists see perspective transformation as a completed process of examining and changing a perspective, then coming to a new way of acting in the context of that changed perspective. The completion of the process and the significant and visible results are the yardstick against which transformative learning is determined to have taken place, or not. An examination of Einstein’s experiences suggests that, while measures of completion and scale are useful differentiators, important transformative learning may be underway even if it fails the yardstick test over a long period of time.

Figure 7 describes three possible levels of meaning transformation, illustrated by Einstein’s learning experience. The first level is the meaning scheme transformation, described by Mezirow (1991) as changes in beliefs, acquired knowledge, or assumptions, which changes may eventually accumulate as full perspective transformations. The next level, the transformed perspective, represents a change in a cohesive body of understanding or meaning. In the case of extending these ideas into a non-personal domain, taking for example the theoretical physics of Einstein’s day, a meaning scheme transformation can be seen to occur when physicists became aware of the results of an
experiment, by the team of Michelson and Morley, which challenged the prevailing conception of the ether.

**Figure 7. Transformation scale for breakthrough learning.**

A transformation in a more substantial perspective occurred later as such meaning scheme transformations accumulated and extended to a new conception of the ether, in this case a shift from the old idea that the ether drags embedded matter, light, and other phenomena along with it (accounting for motion in space), to the new idea that matter is separate from the motionless ether and is affected by changes in the electromagnetic fields within the ether. More than a provocative bit of empirical evidence, this new perspective newly ordered how physicists could make sense of observations in the physical world.

The highest of the three levels of perspective transformation comes from Kuhn (1962), who described paradigm shifts as the stuff of scientific revolutions. A paradigm
transformation is significant enough to change, in a cohesive and comprehensive way, a knowledge field or major aspect of that field. In fact, Mezirow (1991) based his conception of perspective transformation largely on Kuhn’s perspective shifts (a connection which adds weight to the model of knowledge domain breakthrough, scientific or not, as another type of transformative learning). Working in the arena of changes in how people view themselves and others, rather than in Kuhn’s domain of scientific history and philosophy, Mezirow did not require that a perspective transformation change a human’s orientation and behavior as broadly as Kuhn’s picture of paradigm shift as a foundational change in a major sphere of science. However, we can envision these conceptions of change together as cohesive and hierarchical, with meaning scheme changes building to perspective transformations, which may then build to even more significant paradigm shifts, which effectively change a navigation system for a knowledge domain, a human, or a system of human interactions.

Going back to the knowledge domain of theoretical physics for the final illustration, a paradigm-level transformation occurred when Einstein made the ether irrelevant to physics by introducing the special theory of relativity to explain relative perspectives of light transmission in space. The distinctions and transitions between the three levels of perspective transformation, from meaning scheme transformation to the more influential perspective transformation, then to the fundamentally revolutionary paradigm transformation, show important contributions to transformative, or breakthrough, learning occurring at every level. A meaning perspective shift, such as confounding empirical data, does not pass the yardstick test proposed by Mezirow (1991) and others for transformative learning. However, despite the sub-perspective status, the
meaning perspective shift is contributive, provocative learning in a context of larger breakthrough learning.

Similarly, while many perspective shifts would not pass a test for paradigm-level significance, they are not then less accurately defined as an experience of perspective transformation or breakthrough. Further, it is clear that none of these levels of perspective transformation is absolute. Context, perspective, and subjective judgment may be required to ascertain a meaning shift as a transformation in meaning structure or a perspective, or to differentiate a perspective from a paradigm. (In this regard, it must be noted that the terms perspective and paradigm are frequently used interchangeably, and in many contexts represent the same construct, just as shift and transformation may often be used interchangeably to describe the same effect and at other times to indicate different levels or impacts of change.) Thus, the argument here is that while perspective transformations are comparative in scale and impact, they all represent learning in the province of transformation or breakthrough.

Another argument can be made for a more inclusive view of transformative, or breakthrough learning, this time with respect to the level of completeness and integration of the perspective transformation once begun, as illustrated in Figure 8, which shows perspective transformation as a process along a continuum.
As for the escalating scale of impact in perspective transformation, this type of learning can be viewed as more or less complete, comprehensive, or well-integrated, but still representing learning within a context of transformation. The language learner who has not yet attained fluency in, say, German, and may never do so, remains a student of language and may be considered, in context, a speaker of German if the language is integrated, for example, to a sub-fluent level like conversational, traveler’s German. The tourist navigating and relating with a degree of effectiveness in a foreign language is indeed speaking that language, even if he could not be called on to translate a political speech being given in the town hall. In a similar fashion, the journey to achieving a level of perspective transformation is transacted in degrees and milestones, and it can sometimes be difficult and unnecessarily limiting to ascertain where on the journey someone is at a point in time, how long they have been on the journey, where it started,
where it will end, and what will have been achieved in the end, as the case of Einstein’s learning experience illustrates frequently.

In the perspective transformation process, whether personal or non-personal, breakthrough may be a long, winding or cumulative path, with stops and starts, complicating nesting or multi-dimensional perspectives being unwound and re-imagined, and impacts of quite small or very great magnitude showing up in the breakthrough context as the journey unfolds. Take a snapshot of breakthrough learning at a place and time, and the resulting picture may be of a perspective examination halted, or a potential change rejected. Is this the final stop for this transformation journey, or will time and experience bring more disorienting experiences, periods of reflection, forays into practice or exploration (interaction) in an emerging perspective transformation?

Consider whether the aborted perspective transformation was actually a seed planted for the future, or even an ingredient in a more complex and dimensional breakthrough undertaking that will unfold in time. Or was a decision to reject perspective change in order to maintain the original perspective ultimately a more useful or beneficial choice than to engage with a perspective transformation? If so, was the experience of perspective examination alone a worthy experience, despite not resulting in a full process of perspective and behavior change or knowledge creation? At the point of a snapshot, and even of a much longer view on the matter, it may be impossible for an observer or the learner himself to answer these questions with any certainty.

As will be seen in later chapters, this inability to see the full context and end state of learning would have been the case looking at the Einstein data from a slice, even a large slice, in time. He had seeds planted that took root much later, or made conscious
choices to reject a change despite critically examining meanings and some of their implications. He picked up and put down change work, in both the personal and non-personal (or learning project) dimensions. He sometimes experienced a disorienting experience within an active perspective transformation experience, so that an insight or experience in one transformative process acted as a fresh disorienting experience, which would then alter the direction, depth, or significance of the change-learning he was undergoing.

Some of Einstein’s opportunities for perspective transformation, seen from the sidelines of history, might have been helpful to his learning work, or to his personal experience for that matter, but these opportunities passed him by or were resisted to the end. (However, this researcher holds the perspective that quarterbacking perspective transformation for another person, whether from history or real time, is a risky and dubious business and not to be undertaken lightly.) Yet, through it all Einstein was clearly engaged in personal transformational learning and technical breakthrough learning sufficient for any yardstick.

Transformative, or breakthrough, learning can thus be examined from a more wide-ranging perspective, so that observers (whether learners observing themselves, learning facilitators aiming to provide perspective and support on the journey, or researchers making meaning from the data and potential narratives to be found in the field) can benefit from a more comprehensive understanding of the learning experience. When we acknowledge that incomplete or incremental perspective changes are productive, and rich with remaining or evolving potential, we keep the doors open to significant breakthrough learning in any domain.
Transformative Attention

In the model of breakthrough learning presented here, three potential outcomes, hand in hand with three different modes of attention, can be identified for a completed self-directed learning project in which the learner wants to understand or develop something when the solution is not readily evident. The three possible outcomes of a completed interaction stage, illustrated in Figure 9, are acquiring the answer, problem-solving to an original answer, and experiencing highly creative surprising insights. The associated attention modes are solution-seeking, problem-solving, and immersion-incubation in an open, playful stance. Einstein used all three attention modes, and experienced all three types of outcome, many times in the course of his learning project.

Figure 9. The attention and outcome modes of the problem interaction stage.

After Einstein underwent some perspective transformations about the geometric construct of his learning problem in general relativity and gravitation, he found he lacked
the tools to move forward, to interact with and integrate this insight about geometry into the larger learning problem. When he searched for a mathematical form that would allow him to work with the non-linear geometric nature of the curved space-time he believed to be the key to explaining gravity, he eventually found an existing solution. However, the solution wasn’t readily available. He could not pull it from a shelf in the library.

Einstein remembered an aspect of higher mathematics he had heard about in college, which helped him to orient toward the kind of mathematics that he required, if it existed. When he couldn’t find that kind of mathematics in his resource base, he went to his friend, colleague, former classmate, and mathematics professor, Marcel Grossmann, with the parameters for his search. His friend searched, brought potential solutions, and with Einstein determined that one of the existing forms of mathematics (metric tensor calculus, recently invented) should correctly represent the concepts Einstein wanted to work with.

Finding this existing solution, or form of mathematics, to be used as a tool for the project was an answer to that particular segment of his learning problem. Einstein had undergone a perspective transformation process of disorienting experience and critical and imaginative reflection to realize what he needed, and he had interacted with the learning problem (searching for the right tool) until he found one that existed. Skipping over the need to go through the slogging and insight-seeking work of original learning, he was able to shoot straight out of the interaction stage and go straight to integration.

However, applying the solution did not soon or easily yield the solutions to his larger learning problem—understanding general relativity and gravitation. This example shows that a learner can enter the process of breakthrough learning, looking for an
answer that is not readily evident in the present learning environment or resource base, and happily find that the answer does not need to be invented because it already exists. (Thus, breakthrough learning is not the only possible, and certainly not the frequent, outcome of entering the process of seeking new solutions, just as fully formed and integrated personal change is not the only or most frequent outcome of entering the process of questioning and working with existing meaning perspectives, however productive in their own right outcomes of either of these situations may be.)

The example also illustrates the role that the first kind of outcome, acquiring an existing solution, can play in the bigger picture of breakthrough learning. A complex, original learning project is likely to involve many runs through a learning process which will at times deliver acquired learning, at times bring original solutions that remain below a breakthrough contribution level, and at other times result in stunning flashes of illumination and deeply creative breakthrough. All of these outcomes seem called for in big, wild learning problems the likes of which Einstein and other outstanding breakthrough learners are prone to engage.

Each of these outcomes involves a different quality of attention while interacting, practicing, exploring, and experimenting along the search for solutions. The search that ends relatively quickly (compared to the longer process of creating new solutions) in the outcome of acquired learning requires not only defining what is needed and why, and how it will be used (this step applies no matter the outcome type), it entails the work of searching out sources and trails of possible sources, comparing and testing potential solutions against the requirements, and persevering in the search until a solution is acquired or the learner is confident that none exists. When this occurs, when the
searching stage finally fails and the learner commits to continuing the quest by creating or discovering the answers for himself, the quality of attention shifts, as will be seen in the next examples.

While Einstein was applying the new mathematical tools to his problem (and also tossing them out and then dragging them back into the problem over the course of a few years of confused struggle), he was no longer as engaged in that focused, seeing quality of attention. He was still looking for answers, but his attention quality had shifted to a problem-solving mode. He filled pages of his notebook with one attempt, one strategy, one iteration after another to make this mathematical tool deliver a set of gravitational field equations that worked with his conceptual model. He was no longer following a trail out in the world, trying to uncover a solution in the vast, complicated world that met the requirements of his problem. Instead he was applying tools and strategies to a situation in which the outcome must be created from the problem structure and his own efforts.

This might be likened to a computer programmer who has an idea for a function that might be done on a computer, but which he is not sure has ever been attempted. After getting clear about his specification, he scans the universe of computer programs to the best of his ability, looking for something that might be applied to his purposes. Coming up empty, he is still certain that this function would be possible on a computer, with exciting implications, and he is not going to rest until he develops the program, and perhaps a new hardware set to go with it, that will deliver this function. He is still doing what is called searching, but on a new plane. He is now modeling, experimenting, testing, re-conceptualizing, going back into the world for more tools and information, and
repeating until he has enough insights, solutions, and tested successes that he has achieved a breakthrough in computing.

This programmer would have been following the model of learning described by Cavaliere for the Wright brothers, once they had determined that if they were going to fly, they were going to have to build the airplane themselves. Einstein followed this model, applying this quality of attention, when he was in problem-solving mode, working to create original solutions to a learning problem within his larger learning quest. This mode of interacting with the problem is relatively reliable, compared to the final, illumination-seeking mode. It may be the mode most likely to deliver incremental new knowledge to a domain, or to provide incremental solutions within a larger project of breakthrough learning.

In Einstein’s case, his mathematical problem solving did provide the solution he was seeking, after a roller-coaster ride of frustration, changes, published inaccuracies, and lurching steps forward and backward. He underwent a number of perspective shifts about the project and about the use of this tool in the process, so his problem-solving work was complicated by more or less productive insights from some perspective transformations, and unfortunate missteps from others. But the problem-solving mode of applying the tool to the problem eventually yielded results that brought his learning project to a delightful breakthrough conclusion. He did not have to reconceive the structure of the universe at this point, only to solve the supremely thorny problem of finding gravitational field equations that represented the structure he had already conceived in a prior eureka moment. Appropriate field equations finally in hand, he was
able to exit interaction mode and move into integration mode where he, as usual for him, progressed speedily through a cycle of verification and actualization.

If the process of seeking an existing solution to the learning problem is the relatively easiest of the three modes of interacting with that learning problem, and the problem-solving mode is the relatively reliable mode, the transformative attention mode, or spontaneous mode of being open to insight and illumination, is the relatively magical mode. In this quality of attention to the problem, the learner engages the flow process (Csikszentmihalyi, 1990, 1996, 1997) in a variety of ways, and from this quality of attention is more likely to come to surprising insights and outstandingly creative solutions. This last type of attention, playing to an original answer, involves the quality of transformative attention that does not guarantee breakthrough insights by any means, but which, along with the other stages and aspects of the breakthrough model, brings the learner to a breakthrough learning stance, increasing the potential of coming to illuminating insights which will shape a breakthrough outcome.

Carson (2010) describes, in the context of the neuroscience of creativity, this quality of transformative attention as using the spontaneous pathway of creativity. She compares this pathway to a deliberate pathway of problem-solving to a solution. Both are considered creative processes, but the spontaneous pathway features immersion in the problem, along with incubation (together analogous to the interaction stage of the model presented here when undertaken in this mode of transformative attention), leading to illuminating insight and then a final process analogous to the integration process of this Einstein-based model of breakthrough learning. Carson describes the key differences in the deliberate and spontaneous pathways this way:
In [the deliberate] pathway, you *deliberately* and consciously walk toward a creative solution step by step. You feel, as you approach a creative insight, that you’re getting ‘warmer’—closer and closer to the solution. However…the spontaneous pathway allows creative solutions to be generated at an information processing level below conscious awareness. These solutions…will push forward into consciousness as an ‘aha!’ moment. You feel, as you walk down this pathway, that you are wandering through the woods, until ‘voila!’ the trees part before you to reveal the creative solution in all its glory. There is no sense of getting ‘warmer’ or closer to a solution until the insight bursts forth. (p. 56)

Carson explains the spontaneous pathway as the executive function of the brain letting go to some extent the conscious processing of the problem. She explains the benefits of relinquishing control:

This allows more ideas from association centers…that would ordinarily be blocked from awareness to manifest themselves in consciousness…. [and seems to allow] more integration from the nondominant hemisphere of the brain…. The result is that a creative idea may suddenly spring into consciousness when you’re least expecting it. (p. 57)

Flow and play are also prime strategies for developing an open posture toward a learning problem and being in a mode of transformative attention. Breakthrough may require, or perhaps just flourish in the presence of, these insight-friendly conditions or states of being. For example, Csikszentmihaly’s (1993) well-known theory of flow is based on the principles of enjoyment and becoming lost, in a productive and pleasurable sense, in one’s work. The ability to transform regular experiences, like work and
learning, into a state of flow is a capacity that allows for a productive loop of
enjoyment, creativity, and persistence (Csikszentmihaly, 1990). This concept follows on
Maslow’s (1968/1976) description of the peak experience and its impact on creativity
and self-actualization. Csikszentmihaly reflects that “inventors and tinkerers love what
they do, and keep working on their ideas even when the odds for success seem to be
very slim” (p. 254). The motivations for their projects, he explains, are either boredom,
or “because they are confounded by chaos,” (p. 255). Certainly Einstein was confronted
by the chaos which is inherent in any burning question requiring complex learning and
problem-solving.

Neuroscience and psychology increasingly describe a playful approach to work,
or a state of outright play, as an element of creativity and insight. Gallagher (2009) calls
it “an important and under-remarked finding form research on the workplace” (p. 107).
She points out that play, or a playful posture, not only increases flow and engagements,
it helps people with advanced skills and experience to continue to produce and innovate.
Otherwise, “they no longer feel challenged and lose focus” (p. 107). Gallagher reports
on psychologist Gilbert Brim’s findings: “Brim, who’s a strong advocate of just-
manageable difficulty, [says] high achievers…can avoid burnout, depression, and even
self-destructiveness by ‘going wide,’ or focusing on a new vocation or avocation along
with their business as usual” (p. 107).

In fact, Einstein seemed to have an intuitive grasp of this strategy. He practiced
avocations (violin, hiking, daydreaming, and playful correspondence and conversation
with friends) that provided fresh views and states of flow that he reports often allowed
him to achieve spontaneous insights in the process (Freud, 1976). But he also
approached his monumentally difficult learning tasks with a just-manageable approach, so that a sense of play was always possible. Working on the special and general theories of relativity, when he could not get a handle on the bigger picture, or make progress when marching down one path of the project, he would switch his primary attention to other projects where he knew how to proceed and through which he felt he could make an important contribution—his two criteria for choosing a working goal.

Often his alternative projects added an insight or result that could be fed back into the one he was struggling with. The strategy of working on the just-manageable aspects of a project and leaving the overwhelming aspects for later, or working on just-manageable alternative projects while incubating on the tougher one, was part of his modus operandi for success throughout his career.

Brown (2009) points out that what “work and play have in common is creativity….At their best, play and work, when integrated, make sense of our world and ourselves” (p. 127). Brown elaborated:

Play is nature’s greatest tool for creating new neural networks and for reconciling cognitive difficulties. The abilities to make new patterns, find the unusual among the common, and spark curiosity and alert observation are all fostered by being in a state of play. When we play, dilemmas and challenges will naturally filter through the unconscious mind and work themselves out….Necessity only sets the stage for invention and innovation. Play is the mother of invention….Most often, new discoveries and new learning come when one is open to serendipity, when one welcomes novelties and anomalies….As Isaac Asimov said, “The most exciting phrase to hear in science, the one that heralds new discoveries, is not
‘Eureka!’ but ‘That’s funny…’” [What’s more,] having a fierce dedication to grinding out the work is often not enough. Without some sense of fun or play, people usually can’t make themselves stick to any discipline long enough to master it. (pp. 127-128, 134-135, 142-143; see also Austin, 2003; Barer-Stein, 1987; Bergson, 1946/1976; Morgan, 1933/1976; Peirce, 1892/1976, on play, serendipity, surprise, chance, and creativity).

Plato differentiated between play, an unstructured activity for children, and games, which could be instructive and entertaining for older people. Pope (2005) describes a fundamental shift in the Romantic and post-Romantic period, when Plato’s hierarchy was reversed and Kant (an early influencer of Einstein’s thinking) linked creativity to play. Others have offered a “vision of play as virtually synonymous with culture and civilization” (p. 119; see also Kant, 1952/1976). Carl Rogers (1954/1976), working toward a theory of creativity, emphasized a playful spirit:

The “ability to toy with elements and concepts…to juggle elements into impossible juxtapositions, to shape wild hypotheses, to make the given problematic, to express the ridiculous [seems to be a condition of creativity]….It is from this spontaneous toying and exploration that there arises….the creative seeing of life in a new and significant way” (p. 301)

Csikszentmihaly (1993) notes Huizinga’s theory of social institutions evolving from play. Huizinga posits that many elements of our civilization derived from simple pleasure:

[These institutions may have started out] more or less as games that only later [became] serious…Science began as a series of riddling contests, religion as
joyful collective celebrations, military institutions as ceremonial combat, economic systems as festive reciprocal exchanges.…People came together to have a good time, and only later developed rules to make the game more lasting and interesting. (p. 254)

At play, or when a learning project is as play to the learner, the learner “creates a world of his own, or, rather, rearranges the things of his world in a new way which pleases him” (Freud, 1959/1976, p. 49). In the process, he is more able to take risks and make choices; follow his own thought train freely, and have an open and proactive attitude. At play, the learner is expressing and exploring from internal motivations, internalizing the pleasure of the project, the logic of the abstractions he is dealing with, and “the rules of his world, [thus] constructing his own competency” (Reilly, 1974c, p. 16; see also Michalko, 2006; Reilly, 1974a, 1974b, 1974d; Shannon, 1974; Schwartz, 1987; Thorpe, 2000; Whitebread et al., 2005). In fact, when learning and play are viewed and experienced holistically, we avoid a “reductionism [which] impoverishes everyone, [labeling] activities as work or play, or learning…missing the seriousness of play, the delight of good work, the healing that happens in the classroom” (Bateson, 1994, p. 108; see also Csikszentmihaly, 1997 on the paradox of work).

An example of Einstein applying this quality of transformative attention to his learning problem occurred as he struggled toward his special theory of relativity. He had been in problem-solving mode for the past year, trying to solve intractable problems and getting nowhere. Simultaneously, he was working at the Swiss Patent Office, living with his new wife in a small apartment in Bern, trying to write a second dissertation after the
first one had failed, writing review articles for a physics journal, and adjusting to life with a new baby.

Einstein’s ability to maintain an open, insight-inviting stance to his learning problem must have been limited. His favored learning processing strategies (what he did to relax and integrate the learning from his day’s studies, thought experiments, and calculations) over the years had been activities that could have been pulled from the pages of a contemporary (present day, not 1905) book on creativity, flow, and neuroscience (Brown, 2009; Carson, 2010, Gallagher, 2009; Hunt, 2008; Ramachandran, 2011; Reilly, 1974a, 1974b, 1974c, 1974d). These included sitting quietly to “meditate” or “dream” about his problem, going for long walks in the countryside outside the city, conversing with his wife and friends—often playfully—about his ideas, and playing his violin with other musicians. (Also, he is often quoted as saying that he required more sleep than average in order to do his thinking work, and this would fit with contemporary views of processing learning and generating insights, but this researcher found no source evidence for this common attribution to Einstein.) There is no evidence that he was able to practice any of these insight-inviting strategies frequently during this period in his life as he had been able to before, though he continued to work diligently on his learning project.

However much his limited opportunity for relaxed processing of his learning problem may have contributed to his frustrating lack of insight, his eventual eureka moment came hand in hand with some strategies that do prime the learner for insight, which are forms of openness in the spontaneous pathway of creativity. First, he let go.
Letting go shifts mental and emotional focus. This is one way of experiencing what Gallagher (2009) calls *focus interruptus*, a state of shifting attention from intense concentration to a more open and relaxed or playful state in which new brain functions and levels of consciousness can come into play. Gallagher has her own formula for Einstein’s special relativity breakthrough, what she calls a “special alchemy of attention and distraction, information and inspiration” (p. 151). In fact, those are essential ingredients in the interaction stage, in transformative thinking mode, of the breakthrough learning model presented here.

So, out of ideas for how to proceed to a solution, Einstein despaired to the point that he told his friend, schoolmate, and Patent Office colleague Michele Besso that he was giving up the problem. Then he talked through the entire learning problem in a long session with Besso, reviewing the problem with its concepts, angles, successful insights, and ultimate dead ends. That night, he woke from sleep with a joyful flash of understanding of the relative nature of time, that it was not absolute as Newton had imagined. And he knew immediately that this was the open door to the direct solution of his questions about the nature of light’s motion and how it is perceived by observers also in motion.

In his paper on special relativity theory, Einstein thanked Besso, and only Besso, for helping him make this breakthrough (though Besso does not seem to have contributed fresh insights or directions, but rather, more likely, the open presence that characterized his lifelong relationship with Einstein and others, and the opportunity for dialogue with a listener who would understand and engage with the learning problem without taking it over). Besides the breakthrough effects of this full review with Besso (an activity which
represents the immersion in ideas that must precede the letting-go period of incubation, according to the spontaneous pathway model), Einstein could also have credited the sleep he enjoyed after having both released his struggle with the problem and then fully reviewed its aspects with a supportive listener. Buzsaki (2006) reports on sleep’s insight-opening effect:

Perhaps the most spectacular result in this area of research is the demonstration of sleep facilitation of creative insight. Did you ever wake up with the answer to a problem that you could not solve the night before? ….[A research team showed that] a night’s sleep triggered insight….the following morning in most subjects, whereas the same amount of time spent in waking during the day had little effect. These experiments provided the first controlled laboratory experiments for the widely known anecdotes of several famous scientists, writers, and musicians that sleep catalyzes the learning process. (pp. 210-211)

Einstein had other flashes of illumination associated with these types of transformative attention. He had his 1907 eureka moment about a man in freefall not feeling his own weight (inaugurating his foundational equivalence principle for the theory of gravity inherent in the general theory of relativity) after working on an article reviewing the special relativity theory and its implications for physics. This is another example of Einstein’s full review (articulated for an audience) of a thoroughly stuck or apparently hopeless problem, similar to his review of the special relativity problem for his friend Besso in 1905). Then, while sitting quietly, daydreaming at his desk (still in the Patent Office in 1907), he experienced a breakthrough image and thought experiment that propelled him to a completely new stage in his relativity learning project.
Also, Einstein experienced his moment of insight, at age 16, about the physical paradoxes involved with an observer observing a light ray in motion while the observer is also in motion, not long after having reviewed and expressed the learning problem in an essay distributed to an audience of family members and acquaintances, and having also recently let go of his desperate struggles to enter college early and avoid further traumatic public schooling. He found himself, unexpectedly, in a more progressive, learner-centered technical high school in a beautiful part of Switzerland with abundant opportunity for hiking, living as a practically-adopted boarder with a family that delighted, stimulated and supported him, and being, apparently, more able to deeply relax than he had in recent years. In this process of getting his conceptual struggles out in the open and articulated clearly for an audience’s consumption, and letting go of what had been paralyzing struggles and worry in his life, with abundant new opportunity for his favorite insight-friendly pastimes, Einstein experienced the insights that would direct a career of breakthrough learning.

Finally, near the end of the relativity journey, while working at the University of Berlin in late 1915, when he could not get those field equations for a relativistic theory of gravity to work out no matter what direction or strategy he tried, he came to another point of letting go. He gave up the struggle, and spent a couple of weeks reviewing the problem from start to finish. He had also had time to come back from a number of personal blows he experienced in 1914.

The year 1914 was not kind to Einstein, as he experienced a move to a new city and a job with more responsibility at the same time as a final separation and impending divorce from his wife, loss of significant access to his children, a tumultuous period in
the affair with the cousin he would later marry, and the entrance of Germany into World War I, all accompanied by a chauvinistic response to the war by many of colleagues, which horrified Einstein to the point of transforming him from an apolitical man to one who would speak out on matters of peace, politics, and social justice for the rest of his life. Having integrated these blows about eighteen months later, and having decided to let go of his whiplash-inducing strategies and struggles with the relativity theory, Einstein was more relaxed. He entered his immersive review mode, found the problem with his approach, quickly turned around to the correct direction, and within weeks had integrated and published what he now understood into the general theory of relativity.

Every one of the three modes of attention in the problem-interaction stage is useful and productive, and leads to a period of validation and actualization that makes it, one hopes, all worthwhile. Einstein acquired hard-to-find solutions from the human knowledge base. He also put his head down and problem-solved his way to original answers to many of his learning problem questions and requirements. And he kept coming back to downtime activities and more open project stances that allowed him to shift into states of letting go and playing—engaging with intense curiosity, wonder, delight, and flow—with his work once more. The latter mode was consistently associated with his most illuminating ideas and startling breakthroughs within the project.

Ackerman (2000) describes that illuminating playful mode as anything but frivolous (and the impish, long-childlike Einstein would surely agree):

We evolved through play. Our culture thrives on play….Ideas are playful reverberations of the mind. Language is a playing with words until they can impersonate physical objects and abstract ideas….The more an animal needs to
learn in order to survive, the more it needs to play….Play is widespread among animals because it invites problem-solving, allowing a creature to test its limits and develop strategies….we may think of play as optional, a casual activity. But play is fundamental to evolution. Without play, humans and many other animals would perish. (p. 3-4)

All of these findings about attention and attention modes in the interaction stage of breakthrough learning tie the stage back to other elements of the model. Self-chosen learning projects in a deeply meaningful context, fueled by a catalyzing experience (which may itself be a paradoxical thought or surprising insight), oriented by critical and imaginative reflection, attended to deeply by self-directed learners, are the very projects which will put learners into these states of focused attention, searching for solutions, creating original solutions, and patiently staying open and loose to invite the super-creative moments that can make a profound difference in the actualized products of a breakthrough learning project. The next chapter will consider these model stages once more in integrated format, this time in compare-and-contrast mode with other significant models of breakthrough experience from a variety of fields, including adult education, mythology, drama, and the neuroscience of creativity.
CHAPTER IV

PATTERNS IN COMPARATIVE BREAKTHROUGH MODELS

My hero is Man the Discoverer. – Daniel Boorstin

Overview of Comparative Models

Einstein’s learning journey can be examined from several vantage points (see Table 3, below). The integrated model of breakthrough learning, based on Einstein’s learning project in relativity, is a full view of the major elements and project stages from the transformative point of view. It tracks breakthrough work from disorienting experience through critical reflection, problem interaction, and integration. In Einstein’s project, many perspectives had to be acquired and transformed as stepping stones to the stages and levels of understanding that resulted in the relativity theories. (The more impactful of those perspective transformations are described in the next chapter.)

Another angle on the learning journey is the learning process view, a familiar outlook in adult education in which the project is seen from a more operational and external perspective. The major stages from the standpoint of a learning process model are forming the questions, navigating the early project, persevering, and actualizing. Since both the transformational and operational process models cover the same learning territory, just from different layers, it is not surprising that the models line up well in comparison, though the stages and boundaries of each model are not in exact alignment with the stages in every other model.

The disorienting experience from the transformative model occurs within the stage of forming the question, from the operational process model. Critical reflection, though occurring throughout the project, is key in the stage of navigating the early
project, when the project is being clarified and orientation is required. The interaction stage of the transformation model features the work of the persevering stage in the operational model, a stage characterized by theorizing, testing, slogging, despairing, reviewing, and achieving insights. The transformative model’s integration stage is essentially the same as the operational model’s actualizing stage, both primarily involving publishing, in Einstein’s case, as well as empirical verification and other validation.

Table 3

*Comparative Models of Breakthrough*

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<tr>
<td>FORMING QUESTION:</td>
<td>Disorienting experience</td>
<td>Inquiry</td>
<td>Goal setting</td>
<td>Departure (Call to adventure; Mentor; Crossing threshold)</td>
<td>Preparation (Problem-finding; Gather knowledge/skills; Immersion)</td>
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<tr>
<td>Wonder; Acquiring perspectives; Preparation</td>
<td>Critical reflection</td>
<td>Modeling</td>
<td>Focusing</td>
<td>Critical reflection; Problems are shared, Exploring new behaviors</td>
<td>Initiation (Ordeal; Figurative death, Reward / Revelation / Transformation)</td>
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<tr>
<td>NAVIGATING EARLY PROJECT:</td>
<td>Interaction (with data, theory, images, literature, experts, colleagues, etc.)</td>
<td>Experimenting &amp; Practicing; Theorizing &amp; Perfecting</td>
<td>Persevering &amp; Reformulating</td>
<td>Planning action; Acquiring knowledge; Practicing roles; Building confidence</td>
<td>Illumination (Insight, Inspiration)</td>
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<td>Clarifying; Incubating; Modeling concepts</td>
<td>Planning action; Acquiring knowledge; Practicing roles; Building confidence</td>
<td>Planning action; Acquiring knowledge; Practicing roles; Building confidence</td>
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<tr>
<td>PERSEVERING: Theorizing; Testing; Slogging; Reviewing; Despairing; Perspective breakthrough;</td>
<td>Theorizing &amp; Practicing; Theorizing &amp; Perfecting</td>
<td>Theorizing &amp; Practicing; Theorizing &amp; Perfecting</td>
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<td>ACTUALIZING: Publishing &amp; Empirical verification</td>
<td>Integration Actualizing</td>
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*SRT = Special Relativity Theory; GRT = General Relativity Theory; SDL=Self-directed learning*

Cavaliere’s Stages and Cognitive Processes

The theory of breakthrough learning developed by Cavaliere (1988, 1992) to represent the Wright brothers’ development of powered flight is particularly relevant to the model presented here, since it represents the only other model of self-directed
breakthrough learning undertaken in adult education. Cavaliere’s theory was developed using grounded theory methodology to understand a self-directed breakthrough learning project rooted in play and curiosity and brought to fruition in young adulthood at the turn of the twentieth century, leading to technically and culturally transformative results, and catapulting the Wrights from obscurity to lasting global fame. The Wright brothers’ case was different from Einstein’s in several respects. The key differences are that the nature of the Wrights’ breakthrough came from technological invention rather than theoretical scientific discovery, and that it was a collaborative learning project for a pair of independent learners as opposed to Einstein’s mostly solitary endeavor.

Cavaliere’s (1988, 1992) model is built around a nine-step chronological, though recursive, sequence of learning behaviors: (a) model building; (b) research; (c) observation; (d) discussion; (e) contemplation; (f) planning; (g) experimentation; (h) practice, and (i) comparison and contrast. Practice and repetition were the most frequent of the activities, a finding not surprising in light of current theory about extraordinary achievements. Echoing these theorists and Einstein’s own sentiments, Wilbur Wright insisted that “‘you make a great mistake in envying me any of my qualities. Very often what you take for some special quality of mind is merely facility arising from constant practice, and you could do as well or better with like practice’ (McFarland, 1972, p. 306, as cited in Cavaliere, 1988, pp. 146-148).

A set of recurrent cognitive processes also emerged in Cavaliere’s model: “goal setting, focusing, persevering, and reformulating” (1988, p. 158). This grouping of cognitive processes persisted, cycling again and again through each of five stages of the learning project, which were themselves separated by other breakthroughs in the field
(described as corollaries of critical incidents) which in each case pushed the Wrights into a new stage of their project. The stages are: inquiring, modeling, experimenting and practicing, theorizing and perfecting, and actualizing. Throughout those five stages, the nine learning behaviors appeared in cycles.

While identifying the stages in both types of models for the Einstein learning project, based on patterns in learning behaviors, perspectives, cognitive processes, obstacles, breakthrough triggers, motivating factors, and internal and external influences found in the primary data and key technical secondary data sources, the emerging models seemed quite familiar to this researcher. The echoes of Cavaliere’s (1988) model for the Wright brothers were not surprising. Her stage model of self-directed learning was similar to the patterns found for Einstein, despite the distinguishing differences between the two learning projects. Cavaliere’s inquiry stage fits with the Einstein stage of forming the question, which includes wonder, inquiry, acquiring perspectives, and preparation. Her modeling stage lines up in some respects with Einstein’s work of navigating the early project, which included clarifying, incubating, finding footing, and modeling (though Einstein’s modeling work was more abstract and conceptual and the Wrights’ modeling was more concrete, even if on paper). Two stages in the Cavaliere model, taken together (experimenting and practicing, and theorizing and perfecting), describe much of the work that occurred in Einstein’s persevering stage. Cavaliere’s final stage for the Wright brothers, actualizing, is in tandem with Einstein’s stage by the same name.

Cavaliere also described a set of cognitive processes for the Wright brothers’ learning process. While the model developed for Einstein’s work groups cognitive processes with learning behaviors, Cavaliere’s list of key cognitive processes is
analogous to the operational model of Einstein’s learning work. (Extended work in the
grounded theory analysis of the data showed that drawing distinctions between cognitive
processes and learning behaviors in a thought-experiment-driven problem in the abstract
field of theoretical physics was quite difficult and not particularly useful.) Cavaliere
described goal setting, focusing, persevering, and reformulating as the processes that
recurred for each of the stages the Wright brothers encountered in their learning work.
These are analogous to Einstein’s work of the same nature in the four stages in the
operational learning process model. (Since the reformulating process naturally did not
recur in the actualizing stage for the Wright brothers, reformulating is grouped with
persevering, on the same row with Einstein’s persevering stage, before the actualizing
stage.) Obviously, the work of goal setting, focusing, persevering, and reformulating
happened recursively for Einstein as it did for the Wright brothers. But at the macro level,
those processes are good descriptions of the major work and intention of the four
operational learning process stages in the Einstein model.

The stage model for the Wright brothers features transition points triggered by
what Cavaliere refers to as corollaries of critical incidents, or progress events in the world
of airplane development which acted to shift the Wrights’ work to a new stage of
learning. Progress events in Einstein’s field were likewise significant to many of his
transitions from one segment of his learning project to the next, but these segments were
below the level of a full project stage as envisioned here. A more detailed, nine-stage
model for Einstein’s learning work is discussed in the next chapter, including transition
triggers. The more detailed stage model is a more project-specific look at the relativity
project overall, from childhood roots through both relativity theories and the concluding
cosmology theory. However, it is on the same theme as the four step operational model described here, with project-specific stages actually relating to a rhythmic repetition of the four stage model (form the question, navigate, persevere, actualize, navigate, persevere, actualize, navigate, persevere, actualize).

Mezirow’s Transformative Learning Stages

Comparisons with Mezirow’s transformative learning work showed significant similarities once Mezirow’s (1991) ten stages of transformative learning were boiled down to what seemed to be four essential categories within the process. (Breakthrough learning work as experienced by this facilitator of transformative learning does not require, and often does not feature the need for, all of the steps of external validation called for by Mezirow’s model, and many of his ten stages consolidate into the problem interaction and integration categories presented here.) Once the researcher became more convinced of the validity of extending the essential constructs of transformative learning to the non-personal, knowledge transformation domain, the correlations with Mezirow’s categories were not surprising either.

Previous chapters have provided an extensive discussion of the ways in which Mezirow’s (1991) transformative learning stages, which relate to an inner, personal journey of transformation, inform the paradigm breakthrough model of Einstein’s work, which was an external journey of transformation for the field of physics, entailing a corresponding inner journey for Einstein as the learner. For the purposes of comparing the condensed Mezirow stages to the operational learning process for Einstein’s work, the comparisons are as follows. Einstein’s stage of forming the question, which includes events and experiences like giving into wonder and an implacable curiosity, inquiry,
acquiring perspectives, and preparation, relates to Mezirow’s disorienting dilemma and self-examination stages. Einstein’s navigation stage corresponds to Mezirow’s critical assessment, realizing shared problems, and exploring options for new behaviors (assuming the translation of Mezirow’s terms to corresponding activities on the level of work in a knowledge domain, such as translating “realizing shared problems” into “identifying similar issues and searches in the field”). The persevering stage relates to Mezirow’s stages of action planning, acquiring knowledge and skills, practicing roles and feedback, and building confidence, again assuming appropriate translation of terms. The actualizing stage corresponds to Mezirow’s reintegration based on the new perspective.

As with other comparisons illustrated in Table 3, the boundaries for compared stages are sometimes blurred or uneven, and can be further complicated by the actually recursive and sometimes intermixed nature of all stages in all models when considered below the macro level of the project. Yet, without strain, comparison among these various models of breakthrough learning work yields interestingly comparative patterns in the experience and activity of moving from a troubling mystery to a transformative solution. Viewing each level across the models is rather like looking through a prism of multiple outlooks on the same stage in the breakthrough process, and it is an instructive view, and more so as the final two comparisons, coming from outside adult education, reveal.

Campbell’s Monomyth and the Feminine Journey

Joseph Campbell’s work, popularized by Bill Moyers and others, depicts the stories and mythologies of humankind as conforming to a common, meaningful pattern
originating in the universal psyche. Campbell (2008) also credits the shaping of human
culture and advancement around these stories and their primal origins:

It would not be too much to say that myth is the secret opening through which the
inexhaustible energies of the cosmos pour into the human cultural manifestation.
Religions, philosophies, arts, and the social forms of primitive and historic man,
prime discoveries in science and technology, the very dreams that blister sleep,
boil up from the basic, magic ring of myth. The wonder is that characteristic
efficacy to touch and inspire deep creative centers dwells in the smallest nursery
fairy tale….The symbols of mythology are not manufactured; they cannot be
ordered, invented, or permanently suppressed. They are spontaneous productions
of the psyche, and each bears with it, undamaged, the germ power of its source.

(pp. 1-2)

Campbell, born in the United States the year before Einstein published his special
theory of relativity, was educated in part in Europe as an adolescent and young man, and
was heavily influenced by the European intellectual culture at the time. Carl Jung was a
great influence on Campbell’s conceptual developments, particularly Jungian depth
psychology and dream interpretation. Jung, a contemporary of Einstein’s, is known as the
founder of analytical psychology, and is well known for his work in personal
individuation, dream analysis, the collective unconscious, and personality archetypes
(Jung, 1968, 1971). Jung’s work on self-reflection and the archetypes of self was an
influence on Mezirow’s transformative learning theory (Mezirow, 1991).

Campbell’s developmental years coincided with the period in which Einstein’s
theories and cosmology were helping to re-form many aspects of philosophical and
creative thought. Though Campbell was influenced by many thought leaders in psychology, art, and culture, he was also affected by the Einstein-popularized ideas about fields, or, as translated into philosophical and psychological terms, the fields of a non-material continuity between all beings (Osbon, 1991).

As part of his understanding of this purpose-rich connectedness, Campbell also taught about being directed by one’s bliss, “by which Joseph Campbell meant our highest enthusiasm. The word *entheos* means ‘god-filled.’ Moving toward that which fills us with the godhood, that place where time is not, is all we need to do to change the world around us” (Osbon, 1991, pp. 8-9). These echoes of flow theory (Csikszentmihalyi, 1996) and self-determination in learning (Brocket & Hiemstra, 1991; Bouchard, 1994; Merriam, 2001a; Mezirow, 1985) reinforce the critical functions of deep personal meaning (Frankl, 1959/2006) and a natural, open engagement with the learning problem (Carson, 2010) as foundational elements of learning projects that lead independent learners—or mythological adventurers—to breakthrough results.

Campbell’s (2008) conception of the monomyth, or the hero’s journey, is the model that has defined much of contemporary dramatic theory and is a basis for comparison with the breakthrough learning model presented here. Campbell describes the premise of this journey model:

The standard path of the mythological adventure of the hero is a magnification of the formula represented in the rites of passage: *separation—initiation—return*: which might be named the nuclear unit of the monomyth. A hero ventures forth from the world of common day into a region of supernatural wonder; fabulous forces are there encountered and a decisive victory is won; the hero comes back
from this mysterious adventure with the power to bestow boons on his fellow man. Prometheus ascended to the heavens, stole fire from the gods, and descended. Jason sailed through the Clashing Rocks into a sea of marvels, circumvented the dragon that guarded the Golden Fleece, and returned with the fleece and the power to wrest his rightful throne from a usurper. (p. 23)

Distilled from Campbell’s monomyth, Jung’s depth psychology, and Aristotle’s classical dramatic theory, the hero’s journey is now a standard model in literature and drama, serving many forms of storytelling. The model is, according to Vogler (2007), “not an invention, but an observation” (p. xiii), suggesting that this model of breakthrough is long-instilled in human culture and psyche. Campbell’s model is broken down into a number of stages and turning points within each of the major elements. Campbell’s fanciful nomenclature should be considered symbolic for the underlying themes and typical dramatic sequences within the structure of all kinds of real and fictional narratives of adventure, quest, struggle, and victory. Also, not every stage or turning point depicted by Campbell occurs within every tale. Instead, his list depicts common themes and experiences in each of the three major elements.

*Departure* includes the call to adventure, refusal of the call, supernatural aid, the crossing of the first threshold, and the belly of the whale. *Initiation* includes the road of trials, the meeting with the goddess, woman as the temptress, atonement with the father, apotheosis, and the ultimate boon. The *return* includes refusal of the return, the magic flight, rescue from without, crossing of the return threshold, master of the two thresholds, and freedom to live. This narrative structure reveals the classical story form to be about not only seeking, struggling, and finally succeeding or failing at an objective, but also
about a process of transformation or breakthrough, words that are frequently used with reference to the hero’s journey.

These mythical stages have been reinterpreted by Vogler and many others to describe the narrative journey, frequently within Aristotle’s (1924) three-act structure and with reference to other patterns and devices from Aristotle’s classic theory (taken from his *Poetics*), including dramatic reversal, spectacle, and catharsis. A common contemporary presentation of the hero’s journey splits the central element of the monomyth (initiation) into two parts. The resulting structure is used in comparison to the other breakthrough models in Table 3.

The hero’s journey, in four stages, begins with *departure*. This includes the call to adventure, or in terms of the model set presented here, the disorienting experience or the question formed. Something important now looks quite different than it did before. The second stage is *descent*, where the transformation (of the hero or of the world in which he finds himself, or both) begins. The hero undergoes tests and trials, encounters allies and enemies, and approaches the inmost cave, a challenging, danger-laden place where the object of the quest can be encountered. Descent and confrontation of the inmost cave is analogous to the critical reflection required of transformative learning, and of the seeking, stumbling nature of the incubation process and searching for a foothold that occurs in the navigation stage of a breakthrough project, as happened for Einstein.

The third stage of the hero’s journey is initiation, which involves an ordeal, a figurative death, a revelation or transformation, and the grasp of the reward. This meaty, active part of the journey looks very much like Einstein’s stage of interacting with the problem (or, in the operational view of the model, his stage of persevering). In this stage,
which often looks just like an ordeal, he is theorizing and testing; slogging; despairing (a
figurative death); achieving insights, perspective transformations, and revelations, and
finally gaining an understanding of the final solution (the reward).

The final stage is the return, the road back, the figurative rebirth, and the return
with the prize. This is the natural process of actualization, integration, or, as Mezirow
puts it, reintegration. At this stage, Einstein’s work was generally rapid and rewarding,
though it involved a high intensity of focus and outpouring of work as he pulled his
newly won insights and solutions into the full problem: calculating, testing, finalizing
theory, writing, publishing, and receiving empirical results from tests against his theories
(his return with the prize).

Campbell (2008) saw that the mythic structures of pre-modern history apply in
reinterpreted form to the real-life quests of the present day. He lamented the shift from
the communal core of meaning and purpose to the untethered individual, yet he saw
purpose and meaning remaining for a contemporary heroic journey:

Then all the meaning was in the group, in the great anonymous forms, none in the
self-expressive individual; today no meaning is in the group—none in the world:
all is in the individual. But there the meaning is absolutely unconscious. One does
not know toward what one moves. One does not know by what one is
propelled….The hero-deed to be wrought is not today what it was in the century
of Galileo….It is not society that is to guide and save the creative hero, but
precisely the reverse. (pp. 334-337)

The ubiquitous nature of the hero’s journey model has become a source of
frustration and challenge to some who are dissatisfied with the masculine nature of the
structure, stages, language, and goals of the monomyth (Murdock, 1990; Schmidt, 2001, 2005). Reassurances that women can and do play the role of hero in literature, stage drama, and film have not answered the challenge. The hero’s journey itself is considered a masculine form, even when undertaken by a female. It does not help that Aristotle discouraged a feminine form of heroism. When he advised on roles for characters, he said:

   The character will be good if the purpose is good. The rule is relative to each class. Even a woman may be good, and also a slave; though the woman may be said to be an inferior being, and the slave quite worthless. The second thing to aim at is propriety. There is a type of manly valour; but valour in a woman, or unscrupulous cleverness, is inappropriate. (Aristotle, trans. 1924)

Thus, the parallel forms of the masculine and feminine journeys have been developed as a variation, extension, or alternative form of the traditional hero’s journey. Schmidt (2001) describes the masculine journey as one in which “a hero resists inner change until Act III, where he must choose to awaken and find victory or choose to rebel against it and find failure. Traditional cop movies and action films tend to fall into this category” (p. 192). Schmidt portrays the feminine journey as requiring the hero to “go deep inside herself and change throughout the story. This hero awakens in Act I and moves toward rebirth. Movies of the week and character-driven stories tend to fall into this category as well as The Wizard of Oz, Titanic, American Beauty, Mother, The Awakening and Alien” (p. 192).

Heroes of either gender may embark on a masculine or feminine journey, though in fictional forms, according to Schmidt, it is more typical for the male to take the
masculine journey and the female to take the feminine. Each form entails its own detailed structure and turning points, the masculine journey generally paralleling the Campbell / Vogler hero’s journey. However, the feminine journey, though following a classical three-act structure, has a different function, as Schmidt (2005) describes:

The feminine journey as a structure is cyclical in that, in the end, there is a sense that the Journey may continue or that the Main Character will return home to help someone else embark on the Journey she has just taken. This hero has gone through an inner process of change that can only be experienced directly, not shared. The other characters must experience it for themselves to fully understand what the hero went through. In this way, everyone has the potential to be the hero. The Feminine Journey is available to all, not just the rich, strong, or admired. (p. 75)

The relevance of these two forms to the consideration of breakthrough and transformation models is that the hero’s journey is an outer, non-personal journey, though it may contain elements, or a subplot, of inner examination or transformation for the hero. Likewise, the breakthrough learning project in a knowledge domain is an external journey, though the learner may experience inner examination and transformation as part of the experience, as did Einstein. The feminine journey, on the other hand, is an inner, personal journey, though it may take place in and have a transformative effect on external situations. The feminine journey naturally parallels the traditional model of personal transformative learning, in which internal examination, revelation, practice, and reintegration is the point and focus of the experience.
The evolution of traditional transformative learning theory from the inner or intra-personal domain (or in this perspective, the feminine domain) to include an outer form for non-personal breakthrough learning (or, in this perspective, the masculine domain) parallels the evolution of the traditional hero’s journey in dramatic form to include an inner, or feminine, form. As the one-dimensional monomyth was stretched to become multi-dimensional, including both the masculine and the feminine, the personally- and interpersonally-focused transformative learning construct grows to include another dimension of the learning experience: the external, non-personal dimension of domain breakthrough learning.

Carson-Wallas Neurobiological Model of Exceptional Creativity

The final breakthrough model represented in Table 3 is a neurobiological model of creativity. Harvard creativity instructor and researcher Shelley Carson developed a model of exceptional creativity based on contemporary neurobiological research and classical creativity theory. Carson (2010) works from Graham Wallas’s 1931 four-stage model of creativity: preparation, incubation, illumination, and verification (Wallas, 1976). She breaks the Wallas model into two incarnations, or two neurobiological pathways of creativity: the deliberate pathway (or the standard problem solving process), and the spontaneous pathway (the route that best facilitates creative breakthrough). These pathways were described in the previous chapter in the context of transformative attention.

Carson’s work brings a biological explanation for expecting different outcomes from the divergent pathways of the creativity model:
The main difference between these two pathways in terms of neuro-science is that the executive center in the prefrontal cortex—especially the executive center in the dominant left hemisphere of your brain—remains steadfastly in control of the creative process in the deliberate pathway. The executive center directs what you think about and what you call up from your memory bank as you attempt to work creatively. (p. 57)

The temporal and parietal lobes, containing association centers, get to engage in the creative process once the executive center is sidelined, as happens when the spontaneous pathway is engaged, featuring immersion in the problem and then an incubation period of letting go. The experience of sudden insight, which to many people seems to come from outside, “feels foreign to the mind because the person has no memory of having done the work necessary to come up with the creative idea” (Carson, 2010, p. 58). Carson reports on the recent identification of an area in the right hemisphere’s temporal lobe which lights up on scans when an insight breaks through. Carson explains the function of this part of the brain:

[It functions by] the pulling together of broad concepts that are being processed below the level of conscious awareness. These researchers found that not only does this region of the brain activate at the moment of insight, but the brain also produces a high-frequency brain wave called a gamma signal in this same area during the moment of insight. This burst of electricity may allow the brain to direct its attention to the newly formed concept as it suddenly appears in consciousness. (p. 59)
In contrast, the sides of the prefrontal cortex seem to get the most workout when the deliberate pathway is engaged. Brain imaging shows a high degree of focused attention in this pathway. However, when the executive center is not working furiously in this focused and deliberate mode, as happens when the executive center relaxes in the spontaneous pathway of creativity, a network of centers in several other brain regions comes into play. “When you are resting from deliberate thought,” Carson says, “such as when you’re daydreaming or performing an automatic task that doesn’t take too much focused attention, this default network lights up” (2010, p. 60), so that vision and imagination can come to the forefront.

Carson’s model of engaging the spontaneous pathway during the four steps of creativity (as described by Wallas in 1931) is somewhat analogous to the patterns of breakthrough shown in the other models compared in Table 3. The first stage, preparation, entails problem-finding and the gathering of knowledge and skills, which parallels the question-forming, disorienting experience, inquiry, goal-setting, and departure / call to adventure stages of the other models. Carson also includes immersion in this stage, an activity set that might be more closely associated with the second and third stages of the other models.

The second stage of the Carson-Wallas model is incubation, or releasing the tight focus on the project and activating the more receptive state of what Carson calls the absorb brainset. This state may come about through intentional relaxation techniques or the process of falling asleep. It may be that the condition of working in flow (Csikszentmihaly, 1990) aids this state as well, as Carson relates this brainset to heightened curiosity and awareness of the environment, as well as reduced judgment of
others or conditions, situations which may be found in the relaxed attentiveness of the flow state.

Carson (2010) explains that it is not necessary to try to achieve this brain state during the entire stage of incubation, but that “You need to access it before insight or illumination can occur. Neuroimaging studies clearly indicate that people are in this open and receptive state immediately before the moment of insight” (p. 89). This incubation stage relates to the navigation stage of the operational model, as it includes an incubation period in the project when focus is more relaxed and there is more pondering and open-ended exploration. It also relates to the reflection stage, though more appropriately to imaginative reflection than to highly critical reflection. There is also an association with the descent / approach to the inmost cave stage of the monomyth, since the stage in both models suggests an orientation to an inner, or sub-conscious, level that is a precursor to transformative insight.

The third stage of Carson-Wallas’s model is illumination, featuring insight or inspiration. As perspective breakthrough occurs in the persevering, interaction, persevering and reformulating, and initiation/revelation stages in other models in the matrix of Table 3, the association of these stages together is useful and appropriate. Carson’s final stage, verification, includes evaluation, elaboration, and implementation. Certainly this belongs in the family of final stages across the board in the model comparisons, as each model concludes with actualization, integration, or return/rebirth.

The many similarities in these disparately-founded models of breakthrough do not render them redundant. Each illuminates a different context, dimension, or perspective on the breakthrough project. One can stand as a metaphor for the others (and metaphors are
highly provocative of creativity, as discussed later in this chapter). Each model is also a source of story, a form which can inspire, instruct, and shape understanding like no other. The models in Table 3 suggest different avenues for exploration, experimentation, and research which could benefit every context represented by the different models. Those engaged in the creative work described by one model may benefit from method-sharing, strategy-combination, resource-substitution, concept-extension, or provocative dialogue taken from among the realms of the other models. In short, the opportunities to learn, and to enter more deeply creative modes by reaching across the boundaries of these models, are significant for anyone engaged in a project or study of creative breakthrough.

Two essential constructs underlie each of the models discussed here: creativity and genius, or exceptional performance. A deeper look at each of these ideas from a theoretical perspective follows. However, two other considerations for breakthrough models and Einstein’s work are presented as a prelude.

Further Views of the Breakthrough Process

One other process model of note, relevant to this Einstein study, is found in the arena of cognitive theory. Max Wertheimer (1944/1982), one of the founders of the Gestalt school of psychology, was able to interview Einstein extensively about his process of achieving breakthrough in the theory of special relativity, and by extension proposed it as an example of this type of thinking process in general. Einstein’s work had been studied from many important angles, but not from the perspective of a detailed psychological investigation of his thought process leading to breakthrough. Wertheimer must have felt the enormity of his undertaking. “This is quite a task,” he said (p. 213). But Einstein encouraged the undertaking. “I am not sure,” Einstein said once in this
context, “whether there can be a way of really understanding the miracle of thinking. Certainly you are right in trying to get at a deeper understanding of what really goes on in a thinking process” (p. 227). Einstein spent his life committed to getting to “a deeper understanding of what really goes on,” and so his encouragement of Wertheimer was not surprising.

Wertheimer outlined in ten steps his model of Einstein’s thinking process as he developed the special theory of relativity. These steps were: (a) “a passionate desire for clearness” (1944/1982, p. 231); (b) struggling with a paradoxical problem about absolute rest and the velocity of light; (c) accounting for Maxwell’s equations concerning the electromagnetic field, in which the speed of light is a constant and critical variable; (d) integrating into his own views about light speed (when he thought there was no way to do so) the famous Michelson experiment that showed no change in light speed when measured as moving along with the movement of the earth or when moving at right angles to the movement of the earth; (e) dealing with Lorentz’s unsatisfactory (to Einstein) mathematical formulation regarding the Michelson experiment; (f) returning multiple times to the apparent contradictions he perceived in the findings of the Michelson experiment; (g) finally understanding that the gap involved the classical measurement of time, at which point he was able to “take positive steps toward clarification” (p. 219); (h) following the paradigm shift (about measuring time) with a new approach to the essential elements of the problem; (i) at last understanding that “movement in itself…possesses no real sense for us, but only…movement with reference to the chosen observation system” (p. 224), allowing him to complete his thought experiment and articulate his theory of relativity, and then finally (j) expressing his
theory with recommendations for experimental testing, many of which were later performed by other physicists.

Clearly this model, related step-wise, is more in the nature of knowledge scaffolding (what did he solve or learn, and what was he then able to solve or learn as a result?) than of a cognitive theory. However, Wertheimer dives into the underlying organization of thinking and determines that the underlying significance is that “radical structural changes were involved in the process” so that Einstein saw the problem in an entirely different way (1944/1982, p. 230). These were changes “with regard to separateness and inner relatedness, grouping, centering, etc.; thereby deepening, changing the meaning of the items involved, their structural role, place, and function in the transition from structure I and structure II” (p. 230). The point of transition was when Einstein came to see time differently from the classical view.

It must be said that Wertheimer’s model is not widely embraced in the field of Einstein scholarship. Wertheimer, a renowned psychologist and theorist, was a friend of Einstein’s, and they had a number of opportunities to spend time in conversation both formally and informally. Unfortunately, Wertheimer died of a heart condition not long after he sent the draft manuscript of his model to Einstein for review and corroboration. Einstein did not then provide any significant comments on Wertheimer’s model, and the model was published posthumously without his corroboration. In the meantime, doubt has been placed on aspects of the model as Wertheimer was later accused of a bias toward bending Einstein’s process to fit the framework of Wertheimer’s relatively new gestalt theory of psychology (Miller, 1975). Wertheimer’s reports of his conversations with Einstein, and some of the insights provided in the paper related to the first three of
the ten stages, which Einstein is thought to have been able to review and comment on informally, are generally considered valuable additions to the literature (Rynasiewicz, 2000; Stachel, 2006), but the model as a whole has been challenged in ways that cannot be well-addressed in the present day.

In addition to the Wertheimer model, the breakthrough process models compared in Table 3 are not the only process models relevant to Einstein’s work. A number of other models of breakthrough exist in the literature on creativity, discovery, and invention. For example, Hutchinson (1949) developed an early stage-model of significant creativity. The model described behaviors, project stages, and emotional responses, but did not specifically differentiate among those types of elements. The stages entailed preparation; frustration; achievement; the moment of creation and the accompanying emotional responses, and verification. Clearly, the Hutchinson model is similar in pattern to the other models compared in this chapter.

A number of other models of stages and steps for major creative projects have been developed since Hutchinson, but comparing every significant creativity process model to the Einstein models is outside the scope and intention of this dissertation. The point to be stressed instead is that breakthrough learning as represented by Einstein and the Wright brothers looks much like transformative learning, and also like creativity both theoretically and neurobiologically, and like the ancient and contemporary traditions of dramatic storytelling.

Considering the similar patterns and themes among all of these models, it appears that breakthrough journeys are a fundamental part of human experience. We see breakthrough from different outlooks, and call it by different names (including learning,
transformation, scientific revolution, creativity, and story). But by any name or reference point considered here, it seems much the same thing. How rich the learning could be within the pursuit of understanding nuances, similarities, and differences among this variety of breakthrough experience, and applying such a cross-domain understanding of breakthrough to the enhancement of breakthrough opportunities in each field.

In that vein, since creativity, in its many dimensions, is an important underpinning of the breakthrough process from the standpoint of any domain or model, a review of highlights in the field as they relate to breakthrough follows in the next section, along with a subsequent review of the hotly contested realm of theory in genius and exceptional achievement. Together, creativity theory and theories of exceptionality form the richest source of understanding the breakthrough process.

Theoretical Dimensions of the Creativity Field

Creativity theories have surfaced in a variety of disciplines to describe processes, contexts and experiences related to a variety of experiences, including innovation and invention, problem solving, artistic processes and contributions, learning and discovery experiences, scientific endeavors, human cognition, and economic phenomena. Because there does not seem to be a sui generis primary concept to embody and distinguish the key elements of the phenomenon which leads to transformative discovery and breakthrough, the cluster of relevant phenomena is examined here in light of this broad conception of creativity, though the choice of creativity as point of comparison is somewhat arbitrary, given the multifaceted and sometimes ambiguous relationships among related factors.
Creativity and its cousins, breakthrough, genius, and discovery, are an intimidating subject for many to approach. As described in the previous section, even Einstein questioned the ability for anyone, including himself, to understand his own creative process, and his biographers have likewise been reluctant to do so. Weisberg (2006) bemoans two common problems in approaching or communicating about creativity studies. The first is that people think “the topic is so mystical and/or subjective that it could never be captured by psychological methods” (p. 4). The other discouraging perspective, he says, is that “people from inside and outside psychology… [believe that] even if we can define creativity and begin to study it, there is no purpose in doing so, because creativity comes about as the result of almost supernatural powers” (p. 10). Thus, creativity is another impenetrable phenomenon attributable only to the most exceptional people. Weisberg (1986) calls this the romantic view of individuals who “possess extraordinary personality characteristics” and who achieve creative results “through great leaps of imagination which occur because creative individuals are capable of extraordinary thought processes” (p. 1).

Gardner (1993), emphasizing the necessity of a multidisciplinary approach to investigating creativity and creative breakthroughs, quotes a Nobel Prize winner, immunologist Peter Medawar, on the scope and mythological constraints of the problem: The analysis of creativity in all its forms is beyond the competence of any one accepted discipline. It requires a consortium of talents: Psychologists, biologists, philosophers, computer scientists, artists, and poets would all expect to have their say. That “creativity is beyond analysis” is a romantic illusion we must now outgrow. (p. 36)
Though educators did not come to mind when Medawar made that declaration, the opportunity exists for this field to make significant contributions to a multi-disciplinary understanding of creativity as original learning, and of breakthrough learning projects. We certainly have the opportunity to make use of theories, models, and practice implications which would result. The fundamental nature of teaching and learning of all sorts can benefit from a greater understanding of the creative process. Greene (1995) makes a case for creative imagination as the pathway for education:

To learn and to teach, one must have an awareness of leaving something behind while reaching toward something new; and this kind of awareness must be linked to imagination. As John Dewey saw it…imagination is the “gateway” through which meanings derived from past experiences find their way into the present. (p. 20)

Despite this history of limiting beliefs about creativity, creativity has been studied seriously, and with increasing frequency, in recent decades, though the opportunity for further study is immense. In psychology, where much of the research into creativity occurs, “less than 0.2% of the entries in Psychological Abstracts up to 1950 focused on creativity,” then, from 1975 to 1994, that number rose to 0.5%, compared to 1.5% for entries on reading in the same period (Sternberg & Lubart, 1999, p. 3). While the number is not appropriate for comparison, it is interesting to note that a Google Scholar search for scholarly articles, in any field, containing creativity (but none of its additional forms or analogues) in the title, and published between 2000 and early 2011, returned about 14,500 articles. Amazon.com reports 730 books, published between 2000 and early 2011 and assigned to the professional and technical category, which contain the word creativity
in the title. Professional and academic interest in the subject is significant, and if it is growing significantly, there might be potential for a new era of understanding for creativity, breakthrough, and discovery. At some point, the requisite confluence of interest and work will emerge: “The relevance of ideas and events becomes apparent only when there is a group of engaged articulate persons deeply concerned with the same question, problem, or set of possibilities….a critical mass of information and interest must coexist and be in place” (Albert & Runco, 1999, p. 16).

Naturally, creativity is described variously by researchers and theorists across the many fields from which creativity is studied. Originality is at the heart of all creativity, “because creative things are always original,” though “originality is not sufficient for creativity. There must be some usefulness as well. Creative things solve a problem or have some utility of some sort” (Runco, 2007, pp. 379-380). “Creations are products which are both new and valuable,” Rothenberg (1971/1976) affirms, “and creativity is the capacity or state which brings forth creations” (p. 312). Ghiselen (1985) agrees with these two major precepts of creativity, saying that “not even the most vigorously creative minds always find their way…to efficiency” (p. 1-2). Lumsden (1999) calls such definitions of “creativity as a kind of capacity to think up something new that people find significant,” a “mild degree of consensus” among researchers whose differing definitions “carry the unique imprint of their progenitors” (p. 153). Yet Lumsden scales creativity along the two consensus criteria:

Creativity will refer to that tantalizing constellation of personality and intellectual traits shown by people who, when given a measure of free rein, spend significant amounts of time engaged in the creativity process. Outcomes achievable in
principle by creative organisms can vary hugely in their novelty and significance. The Wright brothers, for instance, could have stayed home and made better bicycles instead of undertaking their momentous journeys to Kitty Hawk (Bradshaw, 1996, Freedman, 1991), with all the difficulties and deprivations those entailed. (p. 153)

Scientists, inventors, and other creative types who choose to wrestle with really big problems have to confront the demons of radical originality, risking scorn or rejection in their fields and possibly sacrificing their own beliefs in the process. Holton (1982/2006) describes part of the challenge:

The most creative [scientists], almost by definition do not build their constructs patiently by assembling blocks that have been precast by others and certified as sound. On the contrary, they too melt down the ready-made materials of science and recast them in a way that their contemporaries tend to think is outrageous. That is why Einstein’s own work took so long to be appreciated even by his best fellow physicists….His physics looked to them like alchemy, not because they did not understand it at all, but because, in one sense, they understood it all too well. From their thematic perspective, Einstein’s was anathema. (p. 275)

Of course, creativity is not always radical. Originality, Runco explains, “May take the form of novelty, uniqueness or unusualness, or unconventionality” (p. 379). Utility in creativity also takes several forms. It may be expanded to include generativity (catalyzing additional ideas or creations) or influence (“the new thing changes the way people look at, or listen to, or think about, or do, things like it” [Stokes, 2006, p. 1]). In addition to originality and utility, other common elements of creativity definitions are: intrinsic
motivation, some degree of intentionality (as opposed to pure chance or disinhibition), and likewise some measure of rationality (or connection to existing knowledge or an accepted context of reality) (Blanshard, 1976; Hausman, 1964/1976; Lumsden, 1999; Runco, 2007).

Csikszentmihaly (1990, 1996, 1997), the psychologist and celebrated father of “flow,” a theory that has been called “the most complete explanation of creativity yet offered by contemporary science” (Sawyer, 2006, p. 10), takes exception to some of the basic assumptions underlying most definitions of creativity. Csikszentmihaly believes that despite our customary understanding of creativity as something that happens within the mind of the individual, creativity cannot be confirmed except by external perspectives and comparisons. He views creativity as a “systemic rather than individual phenomenon” because in order to evaluate whether a creative thought is actually both novel and valuable, there must be an “interaction between a person’s thoughts and a socio-cultural context” (p. 23). The systems view of creativity involves the creative person acquiring the rules and practices of a domain, producing “a novel variation on the content of the domain,” and having the variation accepted by the field (Csikszentmihaly, 1999, p. 315; see also Getzels & Csikszentmihaly, 1976; Nickerson, 1999).

Beyond the common features of originality, utility, intentionality, and rationality, features of creativity will vary widely. For example, they may or may not include notable invention, active discovery, serendipity, or thought revolution, even though creativity may be inherent in, or a defining factor for, any of these phenomena. Runco, 2007, describes a number of other variables which compound our understanding and experience of creativity:
Creativity has been defined as a *syndrome* or *complex*. Both of these labels capture the idea that creativity can be expressed in diverse ways (e.g., art vs. science), and sometimes involves different processes (e.g. cognitive or social). It is also influenced by many different kinds of things, including personality, genetic make-up, social and environmental setting, and culture. (p. xi) [There are] connections between creativity and innovation, imagination, intelligence, originality, problem solving, and so on. Each is associated with creativity, but each is also distinct. (p. 376; see also Feldman, 1999; Rothenberg, 1971/1976)

Though intelligence as a breakthrough factor will be addressed as an element of genius, it also bears consideration as a constituent of creativity. While a correlation between creativity and intelligence is sometimes assumed, this has not been shown to be the case. Runco (2007) reports that “creativity tends to be independent of traditional intelligence, but there are also measures and data that suggest an interplay” (p. 376). Further, if intelligence is “the ability to purposively adapt to, shape, and select environments,” the adaptive part of intelligence “may even require one to suppress creativity [as when adapting to] a school or job environment” (Sternberg & O’Hara, 1999, p. 251).

Michalko (2001), a creativity consultant, likewise downplays links between intelligence and creativity, instead attributing creativity more to divergent thinking, or, as he describes it, thinking productively rather than reproductively: “When confronted with a problem, [creative people, regardless of intelligence] ask themselves how many different ways they can look at the problem, how they can rethink it, and how many different ways they can solve it, instead of asking how they have been taught to solve it.”
(p. 2; see also Beardsley, 1976; Guilford, 1967/1976; Mednick, 1962/1976). Roe (1963/1976) agrees. Looking at creative contributions in science, she found that “while a relatively high—perhaps about IQ 120—minimum level of intelligence is needed for scientific contributions, either inventive or elaborative, beyond that level other factors are of more importance, and possession of that or higher intelligence is by no means evidence of high creative potential” (p. 167; see also Wallach & Kogan, 1972/1976).

Imagination is another ingredient of creativity which, as a component of creative work may have much or little to do with the outcome. Also, the relationship depends a great deal on how imagination is defined. Runco has a clear approach which provides a nice contrast between imagination and creativity. He explains that imagination is, naturally enough, the use of mental images to bridge between a sensory reality and a new conception that builds on or springs from the image of that original reality. Imagination can be creative when mental images are “reshaped and recombined into new images” or ideas, though many “creative efforts may be independent of images and imagery” (Runco, 2007, p. 377). In other words, imagination is a form of divergent thinking in which mental imagery plays a key function.

Tharp (2003), a creativity consultant and eminent choreographer, believes that starting with that image of physical reality is fundamental for imagination and all types of creativity. She reflects that “before you can think out of the box, you start with a box” (p. 79; see also Becker, 1998), not an amorphous conception. Aristotle had a similar requirement, describing the creative process as production: “Anything which is produced is produced by something…and from something (and let this be taken to be not the privation but the matter….)….For if we make the form, we must make it out of something
else” (1928/1976, pp. 35-36). Getzels & Csikszentmihaly (1972/1976) also described the need to build creatively out of a specific something:

In picking up, manipulating, exploring and rearranging the objects to be drawn, the artist was trying to formulate an artistic problem….If creativity lies in the artist’s ability to discover and formulate a fresh problem, then his behavior in manipulating, exploring and selecting the elements of his problem…should have been closely related to the creativity displayed in his finished drawing. This we found to be true. (pp. 163-164).

For Einstein, imagination as specific visual imagery was central to breakthrough learning (Einstein, 1979; Holton, 1996). Specifically for the two theories of relativity, he worked with a clear image, and his breakthrough moment, or his ability to finally come out of the “box,” seemed to come wrapped up in a new physical image which appeared, at length, from imaginative thought experiments done from the image that embodied the original question. Einstein obligated imagination as the essence of the work of breakthrough learning in physics:

To him who is a discoverer in this field, the products of his imaginations appear so necessary and natural that he regards them, and would like to have them regarded by others, not as creations of thought but as given realities. (Cited in Northrop, 1970, p. 388)

A particularly visual learner, Einstein (1985) described his thinking patterns this way:

The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as
elements in thought are certain signs and more or less clear images which can be
“voluntarily” reproduced and combined…..The…elements are, in my case, of
visual and some of muscular type. Conventional words or other signs have to be
sought for laboriously only in a secondary stage, when the mentioned associative
play is sufficiently established and can be reproduced at will. (pp. 32-33)

Imagination is also defined less distinctly, in which case it is more difficult to
differentiate from creativity and its other constituents and relatives. For example,
Coleridge distinguished between two forms of imagination (Coleridge, 1817/1976).
Primary imagination, he believed, was “an act of creative perception through the mind, in
which the images are generally fresh and original rather than derived from memory, and
on which all…features arise naturally as…a single undivided whole” (Bohm, 1996, p.
51). Gerard (1945/1985) affirms this process when he insists that “imagination is more
than bringing images into consciousness; that is imagery….Imagination, creative
imagination, is an action of the mind that produces a new idea or insight….The thing
comes unheralded, as a flash, full–formed” (p. 237). Dorothy Canfield (1985) relates such
an experience in the creation of a story, saying “That particular phase of the construction
of the story came and went between two heart-beats” (p. 175).

The second type of imagination Coleridge called fancy, involving rearranging
“distinct images already available from the memory” (p. 51). Fancy applies to many
functions, from routine associations, to self-deception, to design and invention. Both
types of imagination may have applied to Einstein’s experiences, begging the question
about a relationship between the two types. Coleridge was ambiguous on this point
(Bohm, 1996). Bohm picks up the thread and reconsiders primary imagination as “images
of creative and original insight” and fancy as a display of “the more mechanical and routine aspects of thought,” with creative thought moving “between the extremes of imaginative insight and imaginative fancy” (p. 52).

By way of example, Bohm (1996) deconstructs, starting with the story of the falling apple, Newton’s discovery that (by gravitational effect) the moon is falling:

The movement (sic) of insight in which Newton suddenly realized that the moon is falling, even though it never reaches the earth….was an extreme example of something that everybody experiences when he is thinking about a problem containing a number of contradictory…factors. Suddenly, in a flash of understanding, involving in essence no time at all, a new totality appears in the mind, in which this contradiction and confusion have vanished. The new totality is at first only implicit…through some mental image…which contains the main features…. [and may be called] imaginative insight (or creative imagination)….From this apprehension, the mind can go on to think and to reason out more and more of the consequences….It is in this latter process that imaginative fancy (or constructive imagination) begins to play an important part…. [leading to] a hypothesis [which, passing experimentation] is accepted as a particular realization of the primary insight. (p. 54)

Even when visual imagery is not at play, it is useful to consider this model of coping with the “contradiction and confusion” which are part of the process of any significant breakthrough. Breton described the creative potential of paradox and incongruity:
It is the marvelous capacity to grasp two mutually distant realities without going beyond the field of our experience and to draw a spark from their juxtaposition; to bring within reach of our sense abstract forms capable of the same intensity and enhancement as any others; and, depriving us of any system of reference, to set us at odds with our own memories. (Ernst, 1920/1985, pp. 60-61; see also Koestler, 1964, 1976)

With regard to this magic of juxtaposition, whether visual or otherwise, Crovitz (1970/1976) asserts, rather flippantly, that “all there is to discovery and invention is putting a couple of old things in a new relation” (p. 273). Rothenberg (1971/1976) situates this principle in Janusian thinking, a “form of cognition that usually appears early in diverse types of creative processes, in art as well as in science” (p. 311). The term was coined by Rothenberg, who named the concept after the Greek god Janus, the two-headed god of gateways. Janusian thinking, today a commonly used tool for strategy and planning work, describes the ability to hold and work with multiple perspectives at the same time, or to form or experience “a simultaneous conceptualization of opposites” (p. 314). Gould (1996), distinguishing cultural progress from natural evolution, spoke not to this juxtaposition of opposites but, similarly, to the power of combining ideas from divergent sources: “Amalgamation and anastomosis [the recombination of two previously branching paths] of different traditions [result in] the explosively fruitful (or destructive) impact of shared traditions [which] powers human cultural change” (p. 221).

This facet of creative thinking—the latent power of differences considered in concert—may serve to loosen “the mortar holding the old ideas together,” for “there is…assumed to be a tension between knowledge and creativity” (Weisberg, 1999, p.
Creative thinking seems to require the breaking down of old knowledge, experiences, and images, in addition to building from them, and, probably far more difficult, the will to eliminate ideas and beliefs that held together the old ways of seeing.

Unlike the great variety of thought around imagination and creativity, innovation and creativity are easier to compare. Understandably, innovation is intensely studied in the business world, but the precepts and theories apply to many fields, from the sciences to the arts. Innovation is the development of beneficial ideas and applications which are new in the context of a group or society, or which challenge the status quo (West & Farr, 1991; West & Rickards, 1999, as cited in Runco, 2007, p. 381). Given the special importance of utility to innovation, efforts to understand innovation tend to focus on creating and selling many iterations of novel utility (Nayak & Ketterinham, 1986), as seen, for example, in the motivation/ability framework (Christensen, Anthony, & Roth, 2004) which describes motivation (or market demand) and ability as the two essential inputs to innovation.

Berkun (2007) says innovations are developed and adopted “gradually and intuitively as part of the experiment that is life” (p. 28). There is also an important theory of the diffusion of these innovations, describing how ideas are spread through communication channels and social systems in a five-stage process, starting with knowledge and progressing to persuasion, decision, implementation, and confirmation (Rogers, 2003). Innovation, then, is distinct from creativity, which is “often self-expressive and intrinsically motivated…whereas [innovation] is driven by extrinsic incentives” and “the need to surpass previous standards” (Clydesdale, 2006, p. 21, as cited in Runco, 2007, p. 356). Innovation, which may not involve significant or global
originality, is eclipsed in this way by creativity, which “may benefit from extreme originality” (Runco, 2007, 383).

Invention is yet another phenomenon with ties to creativity. Invention, as Weber (1992) describes it, “begins with need, branches into want, and flowers with possibility” (p. 245), another model fundamentally rooted in utility. Creativity need not lead to the invention of a product, though it may. Invention, though, is essentially creative, especially as defined by patent law as “new, useful, and unobvious” (Huber, 1993, p. 232, as cited in Runco, 2007, p. 390). However, invention, the particularly utilitarian incarnation of creativity, especially requires good judgment. “To create consists precisely in not making useless combinations and in making those which are useful and which are only a small minority. Invention is discernment, choice” (Poincaré, 1915/1985, p. 24).

Hadamard (1945) confirms this point encouragingly, suggesting that the conscious mind is well outfitted for identifying the fruitful creative combinations from the multitude of mostly non-fruitful iterations developed by the unconscious mind when confronted with a provocative problem.

Creativity may be untangled generally from discovery by understanding that “all active discovery assumes a kind of search,” (Runco, 2007, p. 390), leading to finding something tangible or abstract, and “the thinking that led to it or recognizes its value may depend a great deal on creativity” (p. 391), such that even serendipitous discovery may require a creative mind to appreciate and exploit the value. However, creativity need not involve seeking or finding anything. Not everyone makes the distinction between active and passive discovery. Austin (2003) situates all discoveries as implying that what is discovered necessarily existed previous to the discovery:
Something already exists…it has been uncovered and brought to light [yet creativity may necessarily be involved]…[If a scientific principle is discovered,] in order to formulate the principle you might first have had to make a complete break in your traditional patterns of thinking and then develop a brand new concept. Thus, it could be said that Einstein “only” discovered the basic principle \( E=mc^2 \) for it was “there” all the time. Yet this does not detract from the immensity of his achievement, nor does the fact that to express his vision he borrowed five symbols, in use for centuries, and arranged them into a sequence never used before. (p. 101)

### Scientific Breakthrough

Scientific breakthrough is a distinct area of investigation into the creativity phenomenon. Ideas about how scientific thought progresses and revolutionary shifts occur have sparked important debates. The two most enduring players in scientific philosophy in the last century were Karl Popper, a philosopher and professor of economics, and Thomas Kuhn, a physicist and philosopher. Both writing after the introduction of Einstein’s theories of relativity, the two philosophers each questioned the merits of logical positivism but varied in their views on the appearance of new ideas in science.

Popper’s major work, *The Logic of Scientific Discovery* (1934), preceded Thomas Kuhn’s (1962) by a generation. Popper’s views about the process of scientific discovery inspired Mezirow to describe Popper’s work as “a forerunner of transformation theory” (1991, p. 38). Popper believed that “we learn in order to change the structure of our expectations rather than to fill in gaps in knowledge” and that “new knowledge resulting
from problem solving is a correction rather than an extension of old knowledge” (Mezirow, 1991, p. 39). Indeed, Einstein appears to have made his transformative contributions not by filling in gaps but by re-structuring expectations and discarding old ideas.

Popper, who called himself a critical rationalist, took exception with classical forms of positivism, arguing that inductive reasoning was questionable and did not necessarily make good science. He promoted theory building and discovery as a way to expand learning by discarding existing broad concepts and creating new ones as novel experiences are juxtaposed with old ideas (Mezirow, 1991; Popper, 1959). In his view, searching for false, or negative, cases for a theory was the essential path to verifying a scientific hypothesis. This opposed the common view that verification was accomplished by finding cases to justify the premise. Only falsifiable theories, he said, were scientific, and he supported Einstein’s views that quantum mechanics did not reflect reality. He believed scientific progress accumulated as inferior theories were negated, making room for better explanations. A transformationalist indeed, his critical approach to science extended to his social philosophies, and he was a defender of liberal values and social criticism.

Thomas Kuhn, in *The Structure of Scientific Revolutions* (1962), describes scientific revolution not as merely the steady progress of normal science, but also science shifted and turned by occasional revolutions in the path of evolving, and often contradictory, parallel paradigms. These sporadic revolutions rend old worldviews and replace them with radically new models. However, as those variant norms and models evolve, scientists may be ineffective in communicating with each other outside their own
paradigms. In this way, the path of progress is both smooth and jerky, and not necessarily well integrated.

Kuhn’s research interest was driven, as in the case of this dissertation, by curiosity not so much about normal, cumulative original learning but about the exceptional nature of breakthrough, or revolutionary, learning. He described this interest in 2000:

The cumulative conception of scientific development is familiar… Both it and its methodological by-products apply to a great deal of significant scientific work. But scientific development also displays a noncumulative mode, and the episodes that exhibit it provide unique clues to a central aspect of scientific knowledge. (pp. 13-14)

Also moving into the territory of Mezirow’s transformation theory, Kuhn (2000) described three characteristics of scientific revolutionary changes. This first is that “revolutionary changes are somehow holistic. They cannot, that is, be made piecemeal” (p. 28). Next is “meaning change [which] I have been describing…as change in the way [the] referents are determined” (p. 29). Finally, all involve “a central change of model, metaphor, or analogy—a change in one’s sense of what is similar to what, and of what is different….Violation or distortion of a previously unproblematic scientific language is the touchstone for revolutionary change” (pp. 30-32; see also Aubusson, 2002; Gordon, 1976). Lightman (2005) likewise describes the essential role language, and specifically metaphor, plays in scientific advancement:

Metaphor is critical to science. Metaphor in science serves not just as a pedagogical device… but also as an aid to scientific discovery. In doing science,
even though words and equations are used with the intention of having precise meanings….it is almost impossible not to reason by physical analogy, not to form mental pictures, not to imagine balls bouncing and pendulums swinging. (pp. 49-50)

Leaning into a constructivist epistemology, Kuhn (1962) (see also Baltas, Gavroglu, & Kindi, 2000) felt that scientific truth was rooted in a paradigm and a historical context, and may not be absolute. He also promoted the controversial view that scientists can never be entirely objective, independent thinkers and thus should acknowledge the potential impact of their non-neutral positions and experiences. Kuhn also opposed Popper’s view of falsification as the key to validation. He believed it was in the nature of scientific understanding and the natural world that no explanation of a situation would fit every case. The gaps left by negative cases did not necessarily invalidate a theory but were an expected characteristic of all claims to understand reality. He argued that falsification as a substitute for verification would cripple science.

Theoretical Dimensions of Exceptional Learning and Performance

Frequently the label genius is applied to those individuals whose defining achievements transform some aspect of human competency, and we distill, and dismiss, the act of breakthrough with the labels inspiration, intuition, or the interesting blinding flash of insight. However, the nature of genius and its role in breakthrough work is not well defined or understood. On the contrary, it seems that the label “genius” often functions as a curtain of unknowability thrown over individual achievers and their achievements. The event thus becomes a black box, so uncommon and alien that it does not bear close examination. Such a circular justification (the extraordinary achievement is
explained by extraordinary ability, which is accounted for by an extraordinary act of nature, and thus the extraordinary is explained away as... extraordinary) is an insufficient rationalization. Genius becomes “an ‘excuse’ for the unfathomable exception” (Bone, 1989, p. 113). The excuse leaves the phenomenon insufficiently explored, and furthers the belief in a mythology of breakthrough achievements: only extraordinarily gifted people need apply themselves to bold goals or provocative questions.

This predicament is reminiscent of Wheeler’s (2006) concern that great mystery can be obscured by a label. He regrets that “even the word universe, bandied about in many a book, conceals a mountain of ignorance” (p. 213). “Genius” also conceals a fair-sized hill of ignorance. Joyce Carol Oates (2011) shares Wheeler’s frustration as she claims, “We revere a cult of genius—as if genius stood alone, a solitary mountain peak. This is false, preposterous” (chap. 61, para. 5). Einstein himself insisted: “It’s not that I’m so smart. It’s just that I stay with problems longer” (Shenk, 2011, p. 139), and “I have no special talents. I am only passionately curious” (Powell, C. S. et al., 2011, p. 56).

Though special talents and differential innate abilities are not categorically denied by most researchers of the genius phenomenon, a growing body of thought related to creativity, performance, professional achievement, and the matter of innate talent versus learned ability suggests that old perspectives and mythologies about genius may be changing. Researchers are paying particular attention to variables like skill practice, cultural and environmental factors, and paradoxical findings about the super-intelligent and their eventual contributions and personal outcomes over a lifetime (Brown, 2009; Colvin, 2008; Coyle, 2009; Howe, 2001; Miller, 2000; Shekerjian, 1991; Simonton, 1999; Shenk, 2011). Yet, despite this growing general interest in genius and high
achievement, these learners and their learning experiences in adulthood are rarely studied from the perspective of adult education. Certainly, both individual talent and the ways in which it features in high-impact learning merit further understanding.

Though childhood education and parenting theory have acknowledged the unique needs, challenges, and opportunities of the gifted (and often highly independent) young learner, facilitators of adult learners have given scarce attention to the specific requirements of the high-achieving or highly independent mature learner. Greater discernment of the experiences and processes of both apparently gifted learners and autodidacts may additionally help to inform the broader perspective of teaching and learning processes (Candy, 1991).

An evolving landscape of theory about genius attempts to position, define, and explain evidence of various types of extraordinary intelligences and related achievements. Genius as a concept, emerging in the eighteenth century to represent a higher type of human, divinely endowed, a hero, or saint (Kemp, 1989; Murray, 1989a, 1989b; Plato, 1938/1976), came from earlier ideas of genius as “attendant spirit,” natural disposition, or inborn ability (Murray, 1989a, p. 2), or as the genie who can supply one’s dearest wish (Mellers, 1989). Through the centuries, assumptions about and implications of genius have evolved, and mostly endured: divine inspiration as an explanation for seemingly impossible intellectual or artistic feats (Dacey & Lennon, 1998; Most, 1989) or, as for Emerson, genius as “the God within, the self of ‘Self-Reliance’” (Bloom, 2002; see also J. Cameron, 2002; B. Cameron, 2006; Maritain, 1953/1976).

The Renaissance brought an evolving shift in the predominant explanation for genius and remarkable creativity. That shift was from the classical explanation of divine
inspiration to more naturalistic explanations, starting with views of intelligence as a genetic gift (perhaps naturally selected), and extending even to conceptions of extrasensory capabilities (Dacey & Lennon (1998); Galton, 1869/1976; Krippner & Murphy, 1973/1976; Skinner, 1972/1976; Weiner, 2000). Spanning history, we also see genius as the layman’s explanation for technical achievements beyond his ken (Kilmister, 1989) and as an enabler of Romantic aesthetics (Bate, 1989; Norris, 1989).

Genius is also well known as the other face of madness (Andreasen, 2005; Kessel, 1989) or neurosis (Kubie, 1958/1976; Lee, 1940/1976; Lombroso, 1895/1976), or the outcome of particular psychological types and coping mechanisms (Barron, 1969/1976; MacKinnon, 1965/1976; Rank, 1960/1976). Even the mental impairments of the autism spectrum of disease sometimes accompany a form of genius in individuals known as autistic savants, people who may not be functional in daily life or most intellectual capacities, but who possess extraordinary ability in a particular area such as visual memory or music (Dodd, 2005). Bean (2008) notes that the genius-madness connection was made as early as Aristotle’s time:

Two different views of madness and genius are neatly encapsulated in the Aristotelian and Platonic traditions….Aristotle viewed melancholy as a disease, but from which genius might spring, whereas Plato said that sanity was to be cherished, but only up to a point, for he thought that the greatest blessings come from the gods and appear through charismatic manias. (p. 47)

Additionally, genius shows up as an elite phenomenon that is considered to denigrate or stifle lower forms of creativity and contribution around it (Tanner, 1989). Genius has further been described as intuitive or pre-conscious development (Beddow,
Thomas Carlyle’s nineteenth-century sense of genius as exceptional attention and effort actually suggests the more recent view that frequency and intensity of practice, along with factors of environment or opportunity, may contribute as much or more to exceptional achievement than the innate ability with which the exceptional performer is often credited. Difficult, deliberate practice, applied a tremendous number of times, may explain exceptionality in a way that inherent talent cannot, and even calls into question the existence of extraordinary endowments (Colvin, 2006; Shekerjian, 1990). Describing the long years of intense work required by even celebrated composers like Mozart in order to reach notable creativity in their careers, McDermott (2007) comments:

No long engagement, no genius. If great composers learn from participation and engagement, the model genius shifts from smartest to the person with the most relentless practice schedule and attentive friends. Great music should be celebrated: we should play it, listen to it, and then figure out how to support the environments composers [and other original learners] need. (p. 293)

Other recent frames for genius include models of integrated traits including risk taking, vision, perspective shifting, and passion (Shekerjian, 1990); a “Darwinian process of variation and selection” (Simonton, 1999, cover matter); theories of multiple intelligence replacing intelligence as a singular and unitary trait (Gardner, 1997); and assertions of the power of visual imagery and analog thinking processes to lead up to “an
explosion of thought” and revelatory insights (Miller, 2000). Overall, the trend seems to be away from understanding genius, the innate gift, as an excuse for the extraordinary. Howe (1999) even declares that “sophisticated inborn capabilities simply cannot exist. Outside mythology, nobody begins life having proclivities that can guarantee the emergence of high abilities” (p. 188). The contributions and controversies defined by these frameworks are significant to this study of the inner workings of Einstein, “the archetypal image of genius for the twentieth-century,” and a man of “radical creative insight” (Murray, 1989a, p. 1).

Composing a more panoramic and challenging picture of genius, McDermott (2007) situates genius in four politicized domains:

First, and relentlessly first, [genius is situated] in the head, mysteriously so, the stuff of inspiration and then, in retrospect, attribution; second, situated, shared, borrowed, and stolen, the stuff of hard work in an active community; third…the stuff of public relations…; and…under the worst conditions, fought over, fought with, fought against, lorded over, and destroyed, all in all, the stuff of politics in a divided and duplicitous society. (p. 285)

McDermott (2007) explains that the eighteenth century brought to the idea of genius the curse of inherent genius, in which “making ingenious contributions is one thing, being called a genius is another, and being born a genius still a third” (p. 286). In the nineteenth century, genius, as a force of alienation, became more menacing when it became a tool of oppression:

[Genius was] a stereotype in invidious racial comparisons, no less inherent, but especially so for populations accused of having too little genius, blacks (Mosely
2000) and women (Battersby 1989) in particular, or too much of it, Jews (Gilman 1996) and homosexuals (Elfenbein 1999) in particular.

Today, insists McDermott, “genius exists most obviously in institutions that celebrate the success of a few over the many; the normal over the disabled, the talented over the normal, and the genius over the talented,” and also as both “an apology for...failed dreams” (p. 287) and as an excuse for tracking students by class and race since “not everyone can be Einstein” (p. 288). Unfortunately, McDermott concludes, “because it is possible to be a genius, it is possible to be a dunce….Because genius is rare, stupidity is rampant,” thus excusing society from not producing “more competent and promising students” (p. 288). He deplores the situation, since “genius as a genotype [and] an apology for failure makes a terrifying combination” in which “a skewed distribution of wealth and [educational] pedigree attends schools in which everyone must do better than everyone else, and when these conditions are tied to a static biology with degrading theories of disability and race, the situation is dangerous’ (McDermott 1988, 1993; Varenne and McDermott 1998)” (p. 288). At the same time, those who have achieved “colossal learning in the head and hand” may both be complimented and scorned as a genius; in this way, “being called a genius is as lethal as it is promising” in that “a genius label can be perversely productive in divided societies in search of a public enemy” (p. 291), as so many producers of transformative new knowledge and perspectives have found when they suddenly became enemies of the state or the state religion.

As Csikszentmihaly (1996) positions creativity not in the mind of the individual but in a socio-cultural context and systems perspective, McDermott (2007) situates
genius not in cognition but in “people organizing collective problems well defined enough for a solution to be advanced and noticed,” a conclusion he illustrates with a listing of “genius clusters: Socrates, Plato, and Aristotle [who] follow each other in three generations; Confucius, Lao-tzu, Chuang-tzu, Mencius, and Han fei-tzu [who] follow quickly in succession; and Darwin and Wallace [who] state a theory of evolution in the same year” (p. 294) (see also Gladwell, 2008). Not only is genius to be “best understood as everywhere, whenever necessary, wherever possible, whether directed to fixing cars…or curing cancer,” McDermott believes that “any unevenness in its distribution is symptomatic of systemic inequalities” (p. 294), a perspective that seems to dismiss any contribution from innate qualities or abilities. McDermott advises that “people making breakthroughs should be seen as moments in a sequence and not isolated by praise. Geniuses should be celebrated by our continuing their work” (p. 294), a sentiment Einstein likely would have applauded.

Still, society wrestles with how to understand and deploy “the rare person smart enough to solve problems others cannot imagine” (McDermott, 2007, p. 291). True to the hypothesis that great results require more than innate ability, researchers indicate that gifted adults may actually be at special risk for poor outcomes (Peterson, 2002). Some of these adults have trouble establishing a career focus in the face of many talents and interests. Others “frequently change jobs…[since] the gifted can get as much out of a job in a few years as a more normally endowed person would get in a lifetime. Then they look for another outlet” (Willings, 1985, p. 37). The direction provided by Einstein’s persistent, focused curiosity may have mitigated this risk for him. As an eighteen year old, he expressed specific plans for the future: working in the theoretical arm of the
natural sciences, because this is what he liked and where his talent lay, he said, and also because it allowed him the greatest possible independence in a profession. The only waver in his writing voice came when he said “I suppose I will become a teacher” (Einstein, 1987, doc. 22). Since this was not his passion, he eventually managed to be free from teaching duties, maximizing his independence and freedom to do his abstract work. Also working in favor of his escalating contributions was his tendency to find new outlets in learning projects which built on past achievements and skill development. As an independent learner, he didn’t need to change jobs a lot to stay challenged and engaged.

Einstein grappled, with varying success, with other potential obstacles to gifted adult achievement: autonomy, unresolved conflict with parents, and a mature intimate relationship (Brian, 1996; Isaacson, 2007). Achieving “convergence of [these] task accomplishments” supports peace of mind, helping adults concentrate on their important work (Peterson, 2002, p. 16). However, for some gifted adults studied, “conflict may actually have built resiliency and confidence” (Peterson, 2002, p. 16). This evidence of equilibrium and personal and relationship maturity (convergence) in adulthood echoes the success factors of gifted individuals in childhood. Tirri (2000) found that the highest-achieving students were often “independent learners who attribute their academic success to both ability and effort….and have been motivated mostly by their own inner drive, although they credit a conducive home atmosphere and supportive teachers as helpful” (p. 1; see also Howe, 1999; Kline & Meckstroth, 1985).

Einstein also shared many of the situations common to a survey of 400 gifted adults who made outstanding contributions (Goertzel, Goertzel, Goertzel, & Hansen,
2004; see also Holton, 1978, on the psychology and early family characteristics of scientists): a preference for nonformal learning, not liking school or, frequently, his teachers; succeeding in spite of unfavorable conditions, and not easily belonging to the common culture; growing up in a home that valued learning; having a parent who struggled toward his own ambitions, another, highly opinionated, parent, and a dominating mother; parents who held non-conformist views, and a preference for marching to his own tune (Clark, 1971; Dilts, 1994; Fölsing, 1997; Howard & Stachel, 2000; Jammer, 1999).

These trait-based explanations of genius and creativity frequently come under fire. For example, Steven Pinker (2004) is highly critical of the nurture-based accounts, finding instead that genetic inheritance, not upbringing, is the significant contribution parents make to the outcomes of their children. (However, the accounts of a number of scientists about the personal influence of their parents on their development as scientists indicate that they might debate the point with Pinker [Bateson, 2004; Brockman, 2004; Csikszentmihaly, 2004; Davies, 2004; Dyson, 2004; Gell-Mann, 2004; Harris, 2004; Marguilis, 2004; Levin, 2004]. Also, our understanding of the critical influence of the home as an informal learning environment for math and science—clearly a factor in Einstein’s learning project development—would also beg a debate with Pinker’s findings [Callanan & Braswell, 2007; Goldman, 2007].) Creativity consultant Michalko (2001) also debates these attempts to correlate genius with particular traits and conditions, including intelligence. Even assuming a traditional view of intelligence as a single and distinct individual trait, a de facto link to genius is not universally accepted:
Scholars and researchers have tried to study genius by giving its vital statistics, as if piles of data somehow illuminated genius….in the end, the piles of data illuminated nothing….Academics also tried to measure the links between intelligence and genius. But intelligence is not enough….Run-of-the-mill physicists have IQs much higher than Nobel-Prize winner Richard Feynman, whom many acknowledge to be the last great American genius (his IQ was a merely respectable 122). (p. 1)

Even if Einstein’s IQ (which is not known) was not such an important factor in his achievements, it may be significant that he successfully navigated the rocky terrain of gifted adolescence to creatively productive adulthood. Some studies of giftedness suggest that Einstein’s gender may have helped him make that transition. Gifted boys receive fewer conflicting signals about roles, achievement, and identity, and seem to be more able than girls to preserve their high aspirations into and beyond adolescence (Kerr, 1985; Reis, 2002, 2003), a situation Einstein’s classmate, would-be-collaborator, and eventually embittered first wife may have experienced painfully (Overbye, 2000; Popović, 2005; Renn & Schulmann, 1992). Csikszentmihaly (1999) reported, similarly, that “young women in art school showed as much creative potential as their male colleagues, or even more. Yet 20 years later, not one of the cohort of women had achieved outstanding recognition, whereas several in the cohort of men did” (p. 313).

Subotnik (2003) reports that the process of moving from bright adolescence to exceptional contributions in adulthood is a conundrum. In childhood, Subotnik finds, factors like IQ and appropriate challenge are important, but in adulthood more is required.
In order to be gifted, that is, to be exceptional, as one matures, one needs to be increasingly active in one’s own development. You have to develop your hunger, you have to be open to career advice, and you have to hone your social skills or your intriguing persona. (p. 3)

Just as IQ seems to be a poor predictor of significant contributions, measures of exceptional creativity, developed and administered much as psychometric testing is used, have not successfully forecast strong results from those measured as “gifted” with creativity. Policastro and Gardner (1999) report the persistent disappointments:

While these measures are sufficiently reliable, their validly has never been adequately accepted….Indeed, not only do high scorers fail to distinguish themselves in creations that society prizes, but the very “core” abilities that have been captured in the tests seem remote from the lengthy development of skills, and the risk-taking stance, that emerges from the study of lives of highly creative individuals. (p. 213)

The efforts of philosophy and science to explain genius, creativity, and exceptional performance in adults certainly offer diverse and conflicting signals about the breakthrough learners and projects that are the object of this study. Where does genius, in any of its incarnations, fit in the story of individual breakthrough learners? What does it look like, and how does it work in the creative process and field of outcomes? The grounded theory work of this research project likely will likely send the researcher back to the literature of this field many times.

We seem to have an emerging view of a more human, far-ranging, and democratic creativity than previously imagined, with the mythology of genius and the mysticism of
creativity dimming. The shifting language in the titles of two of Simonton’s books on scientific breakthrough exemplifies this change in tone and approach: *Scientific Genius* was published in 1988, while the updated version, published in 2004, is titled *Creativity in Science*. Space is being made in the discussion and theorizing about creativity to see breakthrough, creativity, and original learning as the potential, or in some views, birthright, of far larger numbers of people. “Humans are an enormously creative species,” say Ward, Smith, & Finke (1999). “In a relatively short span of time, geologically speaking, we have gone from fashioning rocks into our first primitive tools to building spacecraft that allow us to retrieve rocks from other planets” (p. 189).

Coyle (2009) shares this philosophy. He is a proponent of the neurologically-based deep practice strategy, which includes the tactics of alternately focusing on manageable chunks of practice and on experiencing the full situation in imitative fashion in order to build neural circuits; attentively repeating a practice to reinforce neural circuits, and developing a fine sensitivity for the feel of mistakes and fine performance in the field of practice. Attending in this way to the particular domain where mastery, creativity, and breakthrough are sought, extraordinary performance is far more accessible than previously assumed. “Although talent feels and looks predestined,” Coyle says, “in fact we have a good deal of control over what skills we develop, and we have more potential than we might ever presume to guess” (p. 73).

Still, some in the creativity field consider creativity an exceptional artifact. Martindale (1999) insists that “creativity is a rare trait” (p. 137) requiring coexisting physiological states, which include defocused attention, associative thought, and “a number of mental representations…simultaneously activated.” Martindale sees such a
convergence of mental states happening infrequently, and generally occurring in “creative people” (p. 149).

Beyond the frequency with which we may be wired or induced to achieve special physiological states of creativity, some people may possess personalities, or personality traits, enabling them to approach creative states more readily. Feist (1999), one of many researchers who have attempted to nail down a creative personality, lists a number of covariant attributes of the creative personality, including “openness to experience, fantasy, and imagination;…impulsivity and lack of conscientiousness;…anxiety, affective illness, and emotional sensitivity;…drive and ambition;…norm doubting, nonconformity, and independence;…hostility, aloofness, unfriendliness, and lack of warmth,…and introversion” (pp. 275-279). Creative scientists, according to Feist, may, in addition to having openness to experience and flexibility, exhibit the traits of “drive, ambition, and achievement;…dominance, arrogance, hostility, and self-confidence, …and autonomy, introversion, and independence” (pp. 280-282).

Csikszentmihaly (1996) seems to disagree with this approach to understanding creativity. To be creative, he says, “a person has to internalize the entire system that makes creativity possible,” (p. 51) but it is “very difficult” to say what type of person achieves this internalization. He adds that “there does not seem to be a particular set of traits that a person must have in order to come up with a valuable novelty” (p. 51). Yet Csikszentmihaly does arrive at a set of situations, if not traits, that facilitate creative success, with a disclaimer: “We don’t really have very sound evidence, let alone proof, but we can venture some rather robust and credible suggestions” (p. 52). His situations for creativity include: “a genetic predisposition for a given domain” (like perfect pitch
leading to creativity in the music domain); “an early interest in the domain,” including “a
good dose of curiosity, wonder, and interest in what things are like and in how they
work;” “access to a domain,” or the opportunities of childhood stimulation, role models,
social networks, and so forth; and “access to a field,” including the social skills to
communicate and interact with others; the ability to live in a geographic center of the
work, such as New York for the arts, and successful competition for limited work
opportunities in the field (pp. 52-54). In each case, however, Csikszentmihaly gives
examples of iconic creatives who succeeded despite deficiencies in these areas. He also
found that the most creative people were oriented toward surprise, and had notable
problem-finding ability (a skill Janesick [2004] extends to problem posing). Then, with
apparent reluctance, Csikszentmihaly addresses the trait he most confidently believes
distinguishes creative individuals: complexity.

By this I mean that they show tendencies of thought and action that in most
people are segregated. They contain contradictory extremes—instead of being an
“individual,” each of them is a “multitude.”…These qualities are present in all of
us, but usually we are trained to develop only one pole of the dialectic….This
kind of person has many traits in common with what…Jung considered a mature
personality. (p. 57)

Csikszentmihaly describes ten dimensions of this mature, creative complexity,
juxtaposing energy and quietude, intelligence and naiveté, playfulness and discipline,
imagination and reality, extroversion and introversion, humility and pride, masculinity
and femininity, rebellion and culture, passion and objectivity, and, finally, creative
suffering with creative enjoyment. Not surprisingly, Einstein gives evidence of
significant complexity, with frequent examples of at least several of these dichotomous traits.

As the following chapters go deeper into Einstein’s patterns of learning and relate the story of his learning journey in terms of individual transformations and key plot points in the learning story, many of the patterns and conditions of breakthrough achievement illustrated in the present chapter will be reflected in the human story of Einstein’s remarkable quest, his victories and failures, and ultimately his breakthrough contribution to revolutionary new perspectives in our understanding of the universe and our experience in it.
CHAPTER V

TRAIL OF AN ICON’S BREAKTHROUGH LEARNING

The most beautiful thing we can experience is the mysterious. It is the source of all true art and science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed. – Einstein

This chapter provides the route of approach which is taken into the story view of Einstein’s learning journey. A high level view of Einstein’s journey of breakthrough to relativity introduces this chapter, bridging the breakthrough models (operational view and transformation view) discussed at length in Chapter IV in contrast with several other breakthrough models. Then the view of the journey as a trail of transformation is established, before the chapter concludes with a synopsis of the operational learning model elements: learning journey stages and the progression of key events and experiences through the breakthrough journey. Chapters VI and VII feature a chart-free, model-free narrative of Einstein’s relativity experience.

It is not possible to know with precision or certainty either the inner or outer pathways of an individual’s complex learning project. When that individual is a figure of history, the challenge is somewhat greater. The opportunity to question and verify is missing, naturally. Also, the previous attention paid to an historical figure is both useful and muddying as so many have retraced aspects of Einstein’s experience from different perspectives and with varying degrees of confidence and eventual acceptance. Even though working mostly from primary data, referencing the secondary perspectives on his journey can be enlightening or distracting. Therefore it must be said at the start that any attempt to explain how such events, both so private and so public, can make no sure
claims but can only attempt to direct light on the subject from new perspectives and hope to ask provocative questions for the benefit of future light-bringers. It is in this spirit that these perspectives on Einstein’s experience are presented.

Views on the Relativity Breakthrough Journey

The operational, or learning process, view of Einstein’s stages toward breakthrough featured the following stages: forming the question, navigating the early project, persevering, and actualizing. Running in parallel, as seen in Table 4 below, is the view of the perspective transformations which helped to guide and energize the project. As discussed earlier, those stages are the disorienting experience, critical reflection, interaction with the problem, and integration. Table 4 offers three ways of viewing Einstein’s experience with his relativity project, first breaking down the work into a view of his journey to the special relativity theory, followed by his work toward general relativity. Finally a meta-view, considering the full trajectory from initial curiosity and wonder all the way to concluding his major work on relativity with a cosmological theory, can be seen from the lens of the four-stage models: the operational/learning process model, as well as the stages of perspective transformation.

Each stage in the two models appeared multiple times throughout the learning project, as cycles of learning behavior were applied to the many sub-problems in his project, and cycles of perspective transformation occurred at many points along the way. However, the four-step rhythm in each stage can be used to represent high-level chunks of the learning project, which is what Table 4 describes.

In early childhood Einstein began forming the questions that led him to his relativity theories. These questions formed largely as a result of disorienting experiences,
like his early introduction to a compass, and immersion in explorations of the subject
both in his mind, from books, and in conversations with his mentors.

Table 4

Views on the Relativity Breakthrough Journey

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<tr>
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<tbody>
<tr>
<td>FORMING QUESTION:</td>
<td>Disorienting experience</td>
<td>Childhood</td>
<td>1905 Post-special Relativity dissatisfaction- 1907 writing relativity review article</td>
<td>Childhood – 26 Wonder &amp; Imagination; Independent learning / play; Formal learning</td>
</tr>
<tr>
<td>NAVIGATING EARLY PROJECT:</td>
<td>Critical reflection</td>
<td>Age 16 Light beam vision – 1902 Lorentz view</td>
<td>1907 Equivalence principle – 1912</td>
<td>Special Relativity Theory / Creating perspective and the initial model (“child’s play”)</td>
</tr>
<tr>
<td>PERSEVERING:</td>
<td>Interaction (with data, theory, images, literature, experts, colleagues, etc.)</td>
<td>1902 Struggle with ether, radiation, long slog – May, 1905 despair, review with Besso, simultaneity revelation</td>
<td>1912-1915 Nonlinear geometry breakthrough (revelation, long slog, despair, premature release, long slog, despair, review, return to original insight)</td>
<td>General Relativity Theory / Long, deep dive; Crowning transformation (most agonizing project and staggeringly impactful)</td>
</tr>
<tr>
<td>ACTUALIZING:</td>
<td>Integration</td>
<td>June, 1905 Rapid theory integration and elaboration; publication</td>
<td>Late 1915 Rapid theory integration and elaboration, publication</td>
<td>Cosmological Model (Completion of search for relativity)</td>
</tr>
</tbody>
</table>
The next major step in his relativity journey came during the period from age sixteen when he held his first provocative thought experiment about the observation of light beams, to 1902, shortly after college, when he was exposed to the views of physicist Hendrik Lorentz. Those views gave Einstein new hope of understanding the ether, or a universe without the ether, and sparked new thought. Many of Lorentz’s ideas seemed intuitively more correct to Einstein than what he had learned before about the nature of light.

This period of time is represented by his work to navigate the early project. Einstein was trying to clarify his thoughts and his questions. In this stage he began modeling concepts, trying them out for fit and inspiration. He basically incubated the project, working along with it but without a well-formed strategy or conceptual underpinning with which to take hold. The transformative stage of critical reflection also symbolizes this period of time, for Einstein’s work and struggles were significantly about making meaning, and making sense, of the many elements, unknowns, and inadequacies of his learning project.

In the third period of Einstein’s work leading up to the special relativity theory, occurring from 1902 until the spring of 1905, Einstein had many distractions. This period of time represented the need to slog and persevere in his personal life, still lacking footing with some key personal transformations, in parallel with the hard work of his learning project. This was a time when Einstein was intellectually lonely after college, painfully unemployed, halfway fighting his parents’ resistance to his forthcoming marriage, seeing his fiancé leave the country to be with her family while she gave birth to, and gave up, their illegitimate daughter in secrecy, then finally getting work at the
Swiss Patent Office, grieving the loss of his father, getting married, and finally welcoming the birth of his first son. Einstein was looking for his footing in both the personal and project contexts. In the operational, or learning process, model, this is the time of persevering, and in the view of the perspective transformation model, this is the time of persevering, and in the view of the perspective transformation model, this is the time of interacting intensely with the many perspectives, both personal and non-personal, that affected the project. Einstein theorized, tested, looked for footing and finally found it, slogged through years of effort and disappointment, questioned himself and his work, despaired, gave up the struggle, and finally had the most significant breakthrough of the special relativity period of the project.

The payoff for the intense period of persevering came for the special relativity project in June of 1905, as the twenty-six year old Einstein was able to take his flash of insight about the relative nature of time and work it through the full problem to understand relative observation and motion. He emerged, in a few weeks, with a paper that extended Galileo’s and Newton’s ideas about motion being relative (we cannot be in motion unless it is with respect to something else) and about the laws of mechanics applying equally in any physical perspective, or reference frame (a concept which seems obvious but is conceptually significant in physics).

Einstein was now able to say that all of the laws of physics, not just mechanics, were the same in any reference frame, something that he had longed to do but which was not possible before the framework of the special relativity theory. In the process, he did away with the idea of the ether, and reconceived fundamental ideas about space and time,
energy and matter. This, clearly, was the stage of actualizing the fruits of his long learning process, and integrating the key perspective shifts which had made it possible.

In similar fashion, Einstein’s journey toward a general relativity theory (which is essentially a new theory of gravitation from a relativistic perspective, resulting in seeing gravity as a result of mass or energy warping a space-time fabric) can be broken down into the four stages. His question-forming and key disorienting experiences occurred in the period after the special relativity theory, from 1905 through 1907. The stage of trying to navigate the early project occurred from 1907 through 1912, between the time of a eureka-producing thought experiment about a man in freefall not feeling his own weight through the point at which he could seriously tackle the development of a new theory of gravitation, through a period of collecting unexplainable paradoxes and troubling insights that together did not seem to help him move forward.

Einstein’s acceptance that he needed a new kind of mathematics in order to work with this problem occurred later in 1912, during the third stage, persevering. And thus began a long, focused, intense period of work, once again featuring theorizing, testing, slogging, making wrong turns, giving up the struggle in order to review everything from scratch, and finally experiencing a breakthrough of certainty about the right strategy. The reward of the fourth stage, actualization, came in late 1915, a year after the start of World War I, as Einstein published his full theory of general relativity and began the long process of validation, largely through the empirical experimentation of others.

The meta-view of relativity as a whole, Einstein’s full relativity learning project, finds the question-forming stage represented from childhood through age 25. This was the period in which he was figuring out just what his questions were and how they fit
together with the knowledge and questions in the field at that time, before knowing that he was going to deliver theories of special and general relativity. The second stage is exemplified by the special relativity theory, which was not only an actualized product in its own right, it also provided perspective and an initial model for the larger work in relativity. Einstein said that in comparison to the rest of the relativity project, creating the special theory was child’s play.

The great persevering stage in the meta-project was clearly the long search for the general relativity theory, or the reimagining of gravity and the fabric of the universe. This was the crowning transformation, the most agonizing, and the most staggeringly impactful. However, the full relativity project was not completely actualized, in Einstein’s view, until he developed a cosmological model in 1919, the first one in scientific history. This model allowed Einstein to use a static model of the universe to account, largely incorrectly as it turns out, for some of the implications of general relativity which were at odds with perspectives he held firmly and dearly, the perspectives of Ernst Mach, who was probably his most influential role model in scientific philosophy during the relativity years.

Trail of Transformations

One of the surprises of this research was just how frequent and project-critical were the perspective transformations Einstein experienced during his learning project. The Einstein data gradually revealed a magnitude and impact of perspective transformation which shifted the theoretical understanding of Einstein’s work from being largely about understanding the learning processes (behaviors, cognitive states, etc.) of a self-directed learner. As a result, while these learning processes and the context of learner
autonomy became no less important to understanding Einstein’s learning project, the transformative elements began to come to the forefront.

In retrospect, it should not have been so surprising that breakthrough learning in a knowledge domain should closely parallel breakthrough processes in the non-personal domain. But the project had to reveal itself, and in time the grounded data evidence compounded to broaden the research filter until breakthrough learning came to be understood as a process with many common features across contexts, just one of which is breakthrough original learning carried out by self-directed learners like Einstein and the Wright brothers, and another of which is personal transformation, a la Mezirow (1991).

By this time in the project, every twist of the data analysis kaleidoscope seemed to bring up further angles on breakthrough process patterns (described in Chapter IV), both patterns already known to this researcher and new patterns appearing in the researcher’s own learning field as the study progressed.

Consequently, this dissertation now features a view on the breakthrough learning process seen through a filter of perspective transformations. An example of some of these perspective shifts for Einstein is seen in Table 5. A longer table, covering a few dozen of the more orienting and important perspective shifts relating to the relativity project can be found in the appendices.
Table 5

Sample Page from Transformation Pathway to Relativity

<table>
<thead>
<tr>
<th>Date</th>
<th>From:</th>
<th>To:</th>
<th>Disorienting Experience</th>
<th>Reflection / Interaction / Insight / Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1883</td>
<td>Unawareness of “hidden forces”</td>
<td>Delighted inhabitant of new world of mystery</td>
<td>DISORIENTING EXPERIENCE: Given a compass to play with; mysterious forces</td>
<td>CRITICAL REFLECTION &amp; PERSPECTIVE TRANSFORMATION: hidden forces are elemental, meaningful, knowable</td>
</tr>
<tr>
<td>1883</td>
<td>Dependence and limitation</td>
<td>Self-reliance and freedom</td>
<td>DISORIENTING EXPERIENCE: Navigating the world on his own: it is good to explore independently and solve your own problems</td>
<td>(PRESUMED REFLECTION &amp; INTERACTION: Considering the meaning and opportunity of this new state of affairs, interacting with parents about new independence); INTEGRATION / PERSPECTIVE TRANSFORMATION: Acting to become a competently independent explorer in the neighborhood with blessing of authority figures</td>
</tr>
<tr>
<td>1884-1894</td>
<td>Self-reliance and freedom</td>
<td>Limitation, duty, coercion // Defensive self-direction</td>
<td>DISORIENTING EXPERIENCE: Losing freedoms to authority, structure, and treatment from private tutors and school teachers: it is not OK to learn freely, creatively, independently</td>
<td>CRITICAL REFLECTION: Struggling internally to reconcile school-based learning and freedom to pursue own learning missions; INTERACTION: Carrying as much learner sovereignty as possible into formal education; INTEGRATION: Asserting learning will, becoming ever more self-directed in response despite authority figures</td>
</tr>
<tr>
<td>1884-1894</td>
<td>Dutiful music practice</td>
<td>Passionate music engagement</td>
<td>DISORIENTING EXPERIENCE: Falling in love with Mozart</td>
<td>CRITICAL REFLECTION: This feels like learning now, and like love; INTERACTION: Joyful, focused practice; INTEGRATION / PERSPECTIVE TRANSFORMATION: Instruction and practice finally become play, and he gains sovereignty as a learner; Music now puts him in a peaceful state and facilitates reflection and breakthrough</td>
</tr>
</tbody>
</table>
Some of Einstein’s perspective transformations were more personal in nature, like his evolving perspectives on the role of the divine in personal life and the natural world, yet these personal perspective transformations had significant impact on the development and direction of his project. Other perspective shifts were more technical, or project-oriented, like the transformative path to accepting the relevance of the geometric space-time view of relativity put forward by colleague, and former teacher, Hermann Minkowski. Also, the transformations vary in magnitude and come in different configurations (individual, cumulative, nested, or individual), as described by the pathways to transformation described in Chapter III.

In each case, a perspective transformation can be represented as a shift from some perspective or paradigm, to a new one, as shown in Table 5. This can be seen as a shorthand way of noting the essence of a perspective transformation. It is a model used in the coaching profession for articulating an individual’s desired or achieved perspective shifts and bringing them into awareness. The transformed views catalogued in the appendix as the trail of transformations (excerpted in Table 5) are woven into the narrative presentation of Einstein’s learning project experience in Chapters VI and VII.

Learning Journey Stages, Goals, and Transitions

As previously discussed, this dissertation presents Einstein’s learning work in parallel models of the perspective transformation process (disorienting experience, critical reflection, interaction with the problem, and integration) and an operational learning process model (forming the question, navigating the early project, persevering, and actualizing. While the trail of transformations described above is Einstein’s learning
project seen through a transformation lens, the lens of the operational learning process model is also instructive and important in understanding Einstein’s project both in terms of adult learning theory and the narrative story of his breakthrough work.

Grounded theory work with the Einstein data revealed long lists of learning behaviors, cognitive processes, motivators, obstacles, internal and external influences, and other angles on his learning work. Through the stage of grounded theory analysis that brings such collections of categories together into a meaningful and grounded conceptual framework, some of these categories and data points were integrated into the transformative process model and others into the operational learning process model.

As these distinctions are, to a large extent, a device for reducing the complexity of interrelated concepts by viewing them from two different lenses, these two models and their outputs should not be seen as representing literally separate learning experiences, as learning is a holistic experience no matter how multi-layered and multi-dimensional it may be on examination. Learning goals, obstacles, behaviors, and influences are interrelated with perspective transformation in real experience. We view them separately here to help with conceptual integration, and to suggest that they offer different avenues of understanding and exploration of the phenomenon of breakthrough learning. However, in the narrative experience, the operational and perspective transformative aspects of Einstein’s work come together, as they should.

That said, the data represented in Figures 9, 10, and 11 below, are a distillation of key aspects of Einstein’s learning process (perspective transformations aside as much as possible) as revealed in the data of this study. Figure 10 is the higher level view of the two figures. It describes the learning process in terms of major stages and transition
points of the learning project. Again, this is a very high level view, brought forward from much more detailed layers of the relativity learning project.

Those detailed layers are rolled up into this high level view, for conceptual purposes and to limit the scope of the discussion here. A somewhat finer level of detail can be found in the narrative description in subsequent chapters, but it became evident that explicating an even finer level view, dealing with more intricate twists and turns of Einstein tackling smaller levels of the relativity learning project and dealing with every relevant learning event is beyond the function and scale of this dissertation, which must be contained at a level to feature and illuminate the derived theory without bogging it down completely in the full depth and complexity of the relativity learning project. Suffice it to say that the concepts and categories offered here also represent, through condensation, a somewhat richer view of Einstein’s project than may be evident in these pages.

The journey stages depicted in Figure 10 features nine stages, separated by what seems to be the key transition trigger, among many, for moving from one stage to the next. This model represents the macro view of the project, including special relativity, general relativity, and cosmology. Patterns and cycles can be seen in the stages and their transition triggers.
Figure 10. Einstein’s relativity project learning stages and transitions.
At the stage level, cycles of floundering and emerging can be seen. The steps of moving forward and actualizing are also cyclical, though they are broken out in the longer and more complex work toward the general theory, and compressed within the emerging stage for the fast-flashing end-stage work toward the special theory. Transition triggers also reveal patterns. The situations of working with under-developed premises, immersion in provocative learning, the full project review, and incomplete actualization are repeating triggers for Einstein to move from one stage to the next.

Within each stage depicted in Figure 10, learning goals were significantly patterned as well. These goals are listed in Figure 11, below. In the first stage of the project, developing the passion and acquiring the preliminaries, two goals which drove learning action appeared, but did not recur in later stages. The first was the goal, or necessity, to comply or compromise. This goal featured when Einstein, as a child, had to—or decided to—cooperate to some degree with a formal learning agenda put forward by his parents or the school system. The other non-recurring goal which drove learning action was the goal of assuming or acquiring self-direction or freedom in the learning environment. This goal does not recur because, once past this stage, autonomy and self-direction became so ingrained, reflexive, or absolute during the learning project that they could no longer be singled out as a driving motivator for a learning action. At this point they were an assumed part of the learning style, not remarkable as a fresh motivator.
First Stage Goals
• Comply / compromise
• Self-direction / Freedom (assumed rather than sought in later stages)
• Experience / understand
• Achieve competence / mastery
• Find direction / purpose

All Other Stage Goals
• Experience / understand
• Achieve competence / mastery
• Find direction / purpose
• Find tools
• Find proof

Figure 11. Learning goals at each stage of the learning journey.

The subsequent stages of the learning journey, as depicted in Figure 10, revealed five learning goals which drove key learning actions. These were (a) the needs to experience or understand a level of knowledge or competence, (b) the drive to achieve competence or mastery, (c) the search for purpose or direction, (d) the search for tools needed for the project (these were often searches for constructs, theories, or mathematical applications that would guide the work or provide a framework for creating solutions), and (e) the need for proof (this included Einstein’s desire to prove an intuitively or philosophically held viewpoint through his own theory construction, to find empirical data which would help with the construction of theory, or validate theory he had already constructed).
Plot and Progression in the Learning Journey

Below the level of the stages, transition triggers, and goals of the learning journey, key learning events plot the journey through the relativity breakthroughs. Figure 12 shows obstacles, obstacle breakers, internal and external influences, and the types of learning activities Einstein was undergoing at the point of key learning events. This is called plot and progression because the learning work can be seen as progressing much as a plot unfolds. Within acts of the play (stages, as in Figure 10), action-driving goals are pursued (as in Figure 11). Obstacles appear, and eventually are overcome, as victory over one obstacle or attainment of one learning goal drives the project forward to the next step, and the next. Along the way, other influences from within the learner and from the outside affect progress positively or negatively.

In the theory development stage of this grounded theory project, the prominent events and experiences, from a high level, were culled down to thirty-five story-movers, spanning the long period of about forty years from youthful wonder and curiosity to the creation of the first cosmological model. When these thirty-five events were considered in light of the associated goals, obstacles, influencers, and so forth, the high level tags for each category, reflected in Figure 12, emerged. Each of these obstacles, breakthrough triggers, etc. was repeated multiple times throughout the set of thirty-five high level milestones in the learning project, making it significant enough to appear in these lists.
Figure 12. Plot progression in the learning journey.

The learning behaviors and cognitive processes employed by Einstein during the relativity project were numerous. These were the direct learning activities, observable or cognitive, which he used while traversing the stages, goals, and key learning events in the project. Each of these learning strategies and behaviors, or cognitive strategies and processes, represents a learning skill which was critical to the project at the stage it appeared and in future stages.

Each of these learning activities can be viewed as a window into observing how Einstein as a learner paid attention to his learning work. As was described in earlier chapters, the bulk of the learning work in a project happens in the stage of interaction with the learning project, and this represents ways and means of paying attention to the learning question as it appears in the mind and in the environment. Every learning...
strategy is one more way of paying attention, and it is through these ways and qualities of paying attention that learning problems were solved, insights and breakthroughs were achieved, and finally learning projects were integrated and actualized. Every new way of paying attention which was mastered in a project stage became one more tool, one more lever, for turning a burning question into a knowledge revolution.

The pattern which emerged for these learning behaviors was that in each stage, a new set of learning behaviors appeared, accompanied by behaviors first seen in the stages before. This pattern continued through the project, with many new behaviors evident in the data for the bulk of the stages, and few new behaviors appearing in the latter stages, as the complement of behaviors accumulated through the project had matured by that point. The key recurring learning behaviors recorded (over 90) when analyzing these thirty-five learning milestones are too numerous to list or discuss in the body of this text, but are found in Appendix C in an integrated view of learning stages and transition points (from Figure 10), goals (from Figure 11), and the new learning behaviors which appeared and would recur from each stage forward.

It must be noted that these learning behaviors may not have, in reality, occurred for the very first time in the stage in which they were noted in the data. Documentary data for an historical individual learning project, while voluminous, cannot be comprehensive. Consequently, the reader is encouraged to consider patterns of evolution in evident learning behaviors as more significant than the certain location in time in which any behavior appeared in the data.

A brief look at the advancement of these learning behaviors through the learning project stages indicates a number of foundational learning strategies occurring early and
being extended or built upon over time. For example, the first stage reveals behaviors like observing and investigating, pondering and reflecting, thinking visually, thinking independently in complex situations, practicing autonomy, and focusing intently. On the basis of such necessary behaviors and mental strategies, a complex independent learning project was able to thrive.

The second stage gives evidence of behaviors like formalizing and sharing thoughts related to the learning project, setting goals, planning experiments and predicting outcomes, and testing mental models. The third stage brings learning strategies that include working to master knowledge bases through independent study, searching for supporting data, replacing failing strategies with new ones, and developing the courage to undertake the study of an intimidating subject. And so, through the project stages the learning behaviors build on the foundations set before, aided by those previously set behaviors as they are recurring at each stage along the way. This unfolding may be seen underlying the learning events as depicted in the narrative of the next two chapters.
CHAPTER VI
YEARS OF WONDER AND THE MIRACLE YEAR

The development of this thought world is in a certain sense a continuous flight from wonder. A wonder of such nature I experienced as a child of four or five years, when my father showed me a compass. – Einstein

Breaking Out of Classical Physics: Introducing an Icon

Albert Einstein did his independent learning work in theoretical physics, and in the process invented modern cosmology (Kolb, 2006; Steinhardt, 2006). His consuming, self-directed projects delivered breakthroughs that radically changed the world of physics, and more. Twenty-two centuries before Einstein, Aristotelian physics assumed the geocentric model of astronomy, fixing a stationary earth at the center of the revolving universe. Aristotle argued for a fixed earth by asking why, if the earth might be moving, something thrown up in the air comes down at the same place (Hoffman, 1983). So, while things could fall to earth or fly across it, the planet remained stationary. Overhead, the view was the “awesome vault of the heavens,” the sky “a sphere rotating majestically…as if attesting to the earth’s cosmic importance” (Hoffmann, p. 5).

Though others argued, from time to time, for an earth in motion, none of their claims was convincing. Finally, in the sixteenth century, with the erudition and mathematics of Nicolaus Copernicus (1473-1543), the earth was officially set in motion, now turning on its axis and wheeling around the sun. Thus spinning, the earth skidded off the main stage of our cosmic perspective. Yet, for all the uproar Copernicus caused with this heresy, the earth really didn’t travel that far. Copernicus introduced a universe centered instead on our own sun, or, more precisely, “the empty, unsubstantial center of
the earth’s orbit” (Hoffman, 1983, p. 12). At least the earth’s solar system remained on the celestial pedestal.

Whatever comforts this sun-centered perspective provided lasted about three centuries, or until Einstein’s dogged curiosity led him to the revolution of relativity. Galileo (1564-1642), born two decades after Copernicus’s death, was little comforted, since he was tried and convicted by the Inquisition for promoting the Copernican model (Mook & Vargish, 1987). In Galileo’s day, Johannes Kepler (1571-1630) devised three rules of planetary motion to clean up Copernicus’s imprecise model, delivering an improved model quite similar to the solar system model taught in schools today (Mook & Vargish). Eventually, Isaac Newton (1643-1727), born in the year of Galileo’s death (when recorded in the Gregorian calendar used at the time in Italy, though not when placed on the Julian calendar), provided a “monumental theory of mechanics” (Mook & Vargish, p. 18) that definitively explained and supported the heliocentric view. Newton’s perspective held until 1905, when Einstein’s decades of private study and conceptual wrestling culminated in his relativistic model of time and space, and eventually of the universe. The special theory of relativity made questions of a universal center meaningless. Einstein’s work broke science out of the bonds of classical physics and opened up a fresh universe. He changed not only time and space, but also history and philosophy, literature and technology. The cosmic pedestal vanished.

Einstein was born into a clockwork universe, a Newtonian world where time and space were separate, absolute, and universal (Magueijo (2006). In Newton’s view, a clock ticking in one place proceeded at the same rate as a clock ticking anywhere else in space. Matter existed in the dimensions of time and space, and was defined by how dense
it was (mass) and how powerfully it could impact the environment (energy). In this classical perspective, a baseball in flight and a baseball at rest had the same mass.

Conversely, though the ball carried substantial energy while in flight, at rest it contained none (Greene, 2005/2006).

Einstein’s break-out insight—the conceptualization of relativity, and the celebrity equation it spawned, $E=mc^2$—changed every bit of this. For one thing, the special theory of relativity unified these previously discrete dimensions of matter (mass and energy):

After $E=mc^2$, scientists realized that [the reasoning about baseballs lacking energy at rest], however sensible it once seemed, was deeply flawed. Mass and energy are not distinct. They are the same basic stuff packaged in forms that make them appear different. Just as solid ice can melt into liquid water, Einstein showed, mass is a frozen form of energy that can be converted into the more familiar energy of motion. (Greene, 2005/2006, p. 288)

The clockwork universe disappeared. Time no longer passed by at the same rate from every perspective. “Einstein showed that if from your perspective someone is moving, you will see time elapsing slower for him than it does for you. Everything he does—sipping his coffee, turning his head, blinking his eye—will appear in slow motion” (Greene, 2005/2006, p. 289). Further, the theory predicts that the faster something is moving, the more slowly time passes in the eyes of an observer. “If we could watch a clock moving by us at nearly the speed of light, we would observe that the clock takes longer to tick off an hour than does our own stationary clock” (Goldsmith, 2006, p. 189).
Wonder and Futility Shape a Calling: Developing Passion and Acquiring Preliminaries

The first known sign of the emerging passion that would fuel a lifetime of world-changing science came when Einstein was a four year old boy, hostage to a sick bed during a childhood illness. His father brought him a compass to play with, and young Albert was quickly through the looking glass and into a world of unexpected magic. More than just musing with common curiosity about the strangely directed movement of the compass needle, Einstein was launched into his own world of passionate wonder.

In the parlance of a more contemporary tale of magic and transformation, he ran through the London train station’s brick wall at platform 9 ¾ and emerged to find the train waiting to carry him to Hogwarts, the school for young wizards, where he would discover and master the magic he seemed born to embody. Einstein, like both Alice (of Wonderland) and Harry (of the wizardly Potters), came to see himself differently ever after this bizarre experience. Now he was starting to develop a new dimension of experiencing himself as an investigative thinker and smitten wonderer, capable of transforming intense curiosity into focused action and broad imagination that eventually would emerge in powerful form in a world hungry for understanding. He also soon found himself deeply attached to an understating of the universe as deeply lawful, and to a belief in himself as able, in time, to plumb the deeply hidden but law-obeying forces, and to conquer their enigmas.

This encounter with his father’s compass was a deliciously disorienting experience for Einstein, one he came to call the first wonder of his scientific awakening. His critical reflection (in the terms of a very young enquiring mind) on not just the mystery held in his hands but on his own prior ignorance of a whole dimension of
meaning and power in the universe, led him to interact with this fresh learning problem until he was clear that his worldview, his perspective on experience, had transformed. There were hidden forces under everything, meaningful and surely knowable.

At about the same time as his introduction to the compass, Einstein had another significant learning event. His parents turned him out to navigate the Munich neighborhood on his own, though they followed him from a distance, unseen, for a time. This was a fine experience in adventuring, in which he got to explore the world unsupervised, on his own terms. As a result, he was using this disorienting experience to shift from dependence and limitation toward self-reliance and freedom as he practiced thinking for himself in challenging situations. He was also able to practice building visual maps of complex spaces, a mental skill he would develop to a fine edge as he progressed through his relativity learning journey. This experience also helped him learn to take risks, value exploration, and believe, for a while, that authority figures encouraged such self-reliance and autonomy.

As Einstein entered school, he experienced a more unhappy disorienting experience as his self-reliance and freedom were taken away, to be replaced by limitation, duty, coercion, and the substitution of the state’s plan for his own learning agenda. The terrifically authoritarian culture of the schools, coupled with a heavy reliance on rote learning, dismayed and infuriated Einstein. However, his burning need to learn prevailed. As he struggled to reconcile school-based learning with freedom to pursue his own learning missions, his independent learning behavior, mostly enjoyed outside class, grew stronger. With his persistent independent learning, certainly helped by a family that
encouraged self-reliance and personal learning agendas, he was able not just to protect but also to refine his learning will.

Einstein’s Uncle Jakob, his engineer father’s business partner in the electricity distribution business, was perhaps Einstein’s earliest mentor in his learning project. Jakob Einstein enjoyed challenging Albert with difficult math puzzles, and keeping the learning environment fun by joking and teasing with Einstein about his work. This naturally strengthened Einstein’s confidence in creative problem solving, as he enjoyed surprising his uncle by finding mathematical proofs and innovative solutions for problems on his own. Just as with his experience with the compass, Einstein continued falling in love with the work that was slowly developing into a cohesive shape of wonderful curiosity and problems to occupy him for a lifetime.

Einstein’s mother insisted on a musical life for her son. She started private violin lessons for him at age five, which he continued through age fifteen, when he was separated from his parents when they moved to Italy and he stayed behind to finish school. Einstein was not happy with this enforced, formal instruction. Early on, he threw a chair at his music instructor. But his mother insisted that he persevere, and he complied. In the process, he strengthened his ability to focus, as well as his tenacity for doing difficult things toward a necessary end.

When he was fourteen, Einstein was surprised by a joyful disorienting experience. He fell in love with Mozart. For the first time, he reported, he was really learning music. As he shifted from being a dutiful practitioner of music to passionate engagement with the learning, he also shifted from work to play. In time he became an accomplished violinist, playing for much of his adult life. Now that he was in love, and playing instead
of working, he also found the music put him in a peaceful state of mind and often facilitated reflection and subconscious associations. He would stop playing, reporting that he had just had the insight he was looking for.

As a boy, apparently well before age twelve and possibly much younger, Einstein became convinced and depressed by what he perceived to be the futility of material striving that seemed to be the main driver of most people. This was a disorienting experience that shifted him out of the childlike trust that adults know how to navigate life, and into the belief that most lives are superficially guided, and miserable as a result. Einstein remembered this as a most painful reflection, and it was one that seemed to haunt him for years, if not all of his life.

While the origin of this perspective shift is not clear, it is possible the tumultuous entrepreneurialism of his father, and its effects on family insecurity, had some influence. In any event, young Einstein was now seeking meaning and purpose that would provide a kind of security that he longed for, yet he was wary, and would become increasingly so, of adult models of life direction. This search for meaning would eventually take him into the arms of the field of science and his relativity learning project.

The intensity of this perspective formation and the meaning it held for Einstein, and particular the power it had to shape his choices for decades to come, suggests that a dual-edged motivation structure may be particularly influential in developing breakthrough learners and breakthrough learning projects. Einstein, as will be seen, spent his lifetime experiencing his work as passionately positive—he used terms like wonder, awe, miracle, and holy to refer to his learning work on many occasions, and also based in
a deep need to escape futility, insecurity, and what he called the merely personal. Wonder and futility drove him, and it was a powerful engine indeed.

When Einstein started school, his parents were required, by state law, to provide religious education, though they were a proudly irreligious Jewish family. They arranged for private religious instruction as required, and in time Einstein found faith and meaning in religion that were a balm for the painful reality of the futilely, merely personal dimension of existence. He came to practice religious laws strictly on his own though his family did not. His perspective shift took him from a search for purpose and internal security to an initial landing place for his desire for a direction and security that comes from outside the self. Religion offered clarity, transcendence, purpose, wonders beyond the world of daily cares, and love, all important to Einstein’s inner world, both as a child and an adult scientist.

By the time Einstein was ten, he had emerged as an autodidact, not just a curious child explorer. During the summer before he was to transition between what would be similar to our elementary schools and junior high school, he decided to spend his vacation working through the entire math syllabus for the first year in the new school, so he would be well prepared for entrance examinations in the fall. This seems to be the start to his use of disciplined study and reflection as key routes to learning, and choosing major intellectual challenges on his own for the satisfaction of the experience and achievement.

The study habit, born of implacable curiosity and an inner direction to follow his own learning agenda, primed him for the appearance of another important mentor in his learning life. When Einstein was eleven years old, his parents began regularly hosting a
young medical student for weekly meals, a tradition in the Jewish community. Max Talmey, the new mentor, appeared at a time when Einstein was still looking for credible, meaningful models for life. With Talmey as model and guide, he fell headfirst into the world of science and philosophy. However, his readings in natural science caused him to question the veracity of many of the stories he had learned in religious training. He came to doubt everything about religion, and later said he had been crushed by the sense of being intentionally hoodwinked by authorities into buying into religious fallacy.

Science, and the example of an intellectually engaging young man of science, was at hand as an alternate rudder for this again-lost boy, and he latched on with apparent relief and delight, engaging in what he called an orgy of free thinking. At this point he also set himself what he later called his supreme goal of developing a mental grasp of the universe. He had transitioned from the perspective of religion as a guide and succor to a terrific sense of loss and anger as the disorienting dilemma and traumatic critical reflection dissolved much of his beliefs. But this experience was a springboard to further perspective transformation, as he examined the constructs and lifestyle offered by science and determined that men of science seemed to have a reliable purpose which he would seek for himself. His learning mission was now framed in meaning and intention, and was launched toward the problem-formation that would soon occur.

A positive disorienting experience, the second wonder described by Einstein, came at age twelve when he came across a book of geometry. Setting out to master this apparent guidebook to the mysterious world of physics, a book of spells and miracles of sorts, he thought of it as the holy geometry book. The clarity and certainty found in coming to understand geometric concepts and the mathematical proof of its principles
was a great inspiration and comfort to a child who was simultaneously wrestling with large-sized issues of meaning, purpose, identity, faith, and disillusionment.

Einstein spent much of his free time with this book now, grasping with delight the relation of geometrical concepts to direct experience. In the process, he developed a strong trust in his own intuitive grasp of what “is.” Einstein’s beliefs, perspectives, values, and paradigms were significantly shaped during this period of his life, and his relationship to this geometry book played an important role in this process. And along the way he was still falling in love with new elements of the curiosity and wonder that was already revealing itself as his life’s purpose.

First, though, young Einstein became untethered in a new way. His time with his mentor, Talmey, came to an end at fourteen. And Einstein was fast approaching the age of mandated military service registration, age sixteen. The militaristic culture of the German government, which spilled over into the school culture, was anathema to Einstein. Military service of any kind was not even an option for him, in his mind, but he had no apparent way out.

Age 15 found him without Talmey, and stuck in a system of school and government for which he seemed to hold principally dread and disgust. At this point his parents and Uncle Jakob moved to Italy for the sake of the business, leaving Einstein to live with family friends and finish high school. Now living without the supportive structure of family, apparently also without his violin lessons, and likely feeling alone in the world and imprisoned by the schooling he loathed and by dread of impending military service, he became quite depressed and, as his sister recalled, highly nervous.
The independent young navigator of Munich neighborhoods seems to have prevailed, however, for he took unilateral action to solve his own problems. He had a doctor declare that he needed to be released from school in order to rejoin his parents in Italy. With the doctor’s statement, Einstein withdrew from school, renounced his German citizenship, and travelled to Italy to find his surprised and dismayed parents. He assured them, though, that he had a plan. He would study to pass the entrance examination to a Swiss technical college, a few years earlier than students are normally allowed entrance. He would establish residency in Switzerland and, in time, become a Swiss citizen. Once again, under his own direction, he was headed toward the life and learning goals he had set for himself.

Coming of Age as a Young Scientist

Age sixteen was a watershed year for the maturing learner. He spent the spring and summer studying for the college entrance exam, and found himself engrossed for apparently the first time in theoretical physics. His learning project began to take on a more focused direction, as he recognized in the physics books the kinds of perspectives and interests that he had developed, this way and that, since encountering his compass as a small boy. Against that backdrop, he wrote and home-published his first article on the emerging learning project. In his private studies he was trying to understand the interworking of the ether, light, relative motion in space, and thermodynamics, all toward getting at the mysterious governing laws and forces of the universe. (Ether was the supposed stuff occupying the emptiness of space, through which light, sound, and other dynamic phenomena must be carried from one point to another.)
Developing a specific focus around the measurement of what was then thought of as an elastic deformation of ether while something moved through it, Einstein set down his thoughts, queries, assumptions, and propositions for experimentation in a paper with a tone and intention similar to that of a professional journal article. His choice to engage the thinking world outside himself in his learning work was a sign of his evolution as learner and a maturing individual.

While it is unclear how many people received a copy of his article, he did send a copy to an uncle and corresponded about it, and his mother made at least one copy in her own hand to deliver to a family friend. A year later he told his mother to take back the copy, because he had decided by that time that something in the article was wrong. His concern for accuracy and desire to be respected and taken seriously is also reflected in the article itself, in which he requests the forbearance of readers for any inadequacies caused by his limited access to literature and data for study. Still, he demonstrated a necessary willingness to tackle intellectual and emotional challenges in service of his mission.

Undertaking this scary and exciting project to stretch his learning to a type of conclusion and share it somewhat publicly was another of many disorienting experiences that kept him growing and learning at this stage of his life. Documents from that time show that he experienced a range of complex emotions around this experience, including anxiety, courage, humility, inadequacy, confidence, enthusiasm, admiration, optimism, and above all deep engagement with his subject.

His reflections from this period indicate that he felt he must discover answers to his questions for himself, and his interaction with his readers indicated that he wished to be taken seriously, as he was coming to take himself seriously as an investigator. Since
he lacked the resources for conducting the experiments he felt were necessary to answering his questions, he outlined a program of experimentation for other researchers to take on. But, as was the case at other times in the future, his mature, confident, and precise language masked an underlying dread that he might be on the wrong path, or making a fool of himself. In fact, he began the article with a hint of this trepidation:

The following note is the first modest expression of a few simple thoughts on this difficult topic. It is with reluctance that I am compressing them into an essay that resembles more a program than a treatise. As I was completely lacking in materials that would have enabled me to delve into the subject more deeply than by merely meditating about it, I beg you not to interpret the circumstance as a mark of superficiality. (Einstein, 1987, doc. 4)

The integration point here, the perspective shift as a learner, was that he had pronounced himself an independent scholar and scientist who wanted to engage with a community of thinkers about the learning problems he cared deeply about. He took the first step from being a consumer, or acquirer of knowledge to being a contributor. He set out a classical theoretical foundation in a mechanical, elastic ether conducting electric and magnetic fields, which in a dynamic state determined wave propagation of light, among other phenomena. From this basis he made predictions about the speed of these waves under certain conditions, which his experimental program should reveal. While his paper was not a stroke of genius or intellectual revolution, his careful development, production, and distribution of the document showed something of the depth of meaning his learning project held for him, as well as a quality of courageous and searching
attention that would carry him into future works of brilliance and daring. He was coming of age as a scientist.

Within a few months of this neophyte publication, Einstein experienced the catalytic question, in his typically visual format, that would drive him into the relativity revolution—a wonderfully disorienting experience which troubled him deliciously and painfully until he solved it over the next two decades from every level possible. He wondered what would happen if he could chase a light ray, or ride on the beam. If he could run fast enough, would the light no longer be moving, since movement, as understood from classical physics, requires being in motion relative to something else? How would the motion of the earth affect all of this? Einstein was troubled and delighted, as with a mystery or puzzle, and he had his learning problem in hand. He had shifted from a general fascination with the underpinnings of the universe to possessing a lifetime model for discovery. His days as a scientist, and as an independent learner moving toward a definite, and ultimately breakthrough, learning problem had begun.

Einstein was not successful in his bid to be accepted early into college, but he found himself instead in a progressive Swiss technical high school which was more to his liking, in circumstances that were freeing and supportive, and it was as he began this more amenable life that he had the thought experiment about the light beam. He continued his studies, formally and privately, and also more happily, and entered college at age seventeen, still earlier than normal. In college he found that his professors did not teach theoretical physics, and had many requirements that did not advance his own learning agenda, so he skipped classes much of the time in order to spend his time studying the contemporary masters of theoretical physics. He began engaging with
revolutionary ideas in physics and philosophy during these independent studies, maintaining his learner sovereignty through college, though at a later high price.

This self-directed engagement with the unconventional ideas of physicists shook his faith in classical physics, though he held fast for quite a while. But his awakening could not be denied, and he came to see and engage with some of the significant challenges to Newtonian physics. At the same time he was working on his key learning project, gathering a new vision for understanding light and relative motion, developing ideas for investigating the relative motion of bodies in the light ether, and trying to find ways to get data to test some of the current thinking in physics so he could have foundation from which to work on his learning project.

Searching for Footing

At twenty-one, as a new college graduate, Einstein published his first scientific paper. The subject was capillarity, and he was looking for a connection between the intermolecular force and gravity, trying to work toward proof of the theory of atoms. The paper was of no great scientific consequence, but it was a way of making his mark as a new professional in the field, despite having no real professional connections. After graduating he found himself unemployed, except for a few stints of substitute teaching and tutoring, for two years. It seems that he had a falling out with his major professor, who, despite Einstein’s high academic standing, did not appreciate Einstein’s impertinent criticism of the department’s inattention to theoretical physics, among other things, nor his poor class attendance. This professor’s recommendation would have been crucial in placing Einstein as an instructor at his alma mater after graduation, as he had expected, or in another educational posting, but the recommendation was withheld.
Everyone else in Einstein’s graduating class received positions readily, but Einstein was left out in the cold both in terms of employment and in terms of getting plugged into the professional network. He wrote letters asking for jobs in positions that would give him exposure and resources to continue his scientific education, but to no avail. (He eventually tried to get a job as an insurance salesman, as he was that desperate.) His rejections accumulated, and finally his father, knowing Einstein’s anguish and the family’s financial straits, wrote a letter (unbeknownst to Einstein) to a physicist Einstein wanted to work for, elegantly begging him to take on Einstein as an assistant, but the intervention was in vain.

Einstein was also intellectually lonely and hungry. He needed the stimulation of intellectual dialogue and camaraderie he enjoyed in his college years, and he chafed without it. Yet he continued to approach his private scientific work with joy and wonder, still falling in love with new ideas, marveling at new paradoxes, finding new heroes of theoretical physics in his readings, and still passionately pursuing his chosen purpose in life. Unsure, though, how to proceed with his learning project at this point, he decide to work toward formal principles by conceptual theoretical work rather than toward comprehensive laws formed from existing data, a strategy he would need to follow for years. This was not, however, without a strong undercurrent of doubt and disappointment, as Einstein (1979/1949) lamented:

Gradually I despaired of the possibility of discovering the true laws by means of constructive efforts based on known facts. The longer and more desperately I tried, the more I came to the conviction that only the discovery of a universal formal principle could lead us to assured results. (p. 49)
Einstein was learning to release an old strategy that had been worked to a dead end and beyond, and replace it with a more fruitful strategy, once more moving forward toward his learning goals. He also inaugurated another strategy of learning and production that would become one of his hallmarks: working on more than one simultaneous, often synergistic, project at once. In the intellectually and personally lonely, rejection filled period of 1900-1901 Einstein worked on two more papers, extending prior work and engaging with new ideas, which would find later publication. He also worked on a dissertation, which would later be withdrawn after submission.

Early 1901 brought another significant perspective shift for the learning project. Einstein had been enamored with Maxwell’s electromagnetism during his private studies in college, and as he studied Maxwell’s work he had grown in confidence that this theory would develop into a powerful challenge to classical physics. His hold was loosening on the perspective that classical physics from Galileo’s and Newton’s days must persist, but it was being replaced by the view that electrodynamics would be the usurper in many respects. Then he came across Max Planck’s work on radiation. (In this context, radiation refers to energy radiating from, say, a light source; this was not radiation in the sense of radioactivity as we think of it commonly in this nuclear age.)

Planck’s work introduced a paradox that questioned what was known about the structure of radiation and also threatened hopes that electromagnetism would provide a way out of some of the conundrums emerging in classical physics. Suddenly neither classical mechanics nor electrodynamics could be relied on as valid for the situations Einstein and others were trying to understand. This problem was one Einstein called a crisis in physics; it was a crisis in perspective transformation, as was, earlier, Maxwell’s
electromagnetism. Planck, in effect, was introducing a quantum world, the implications of which neither he nor Einstein liked.

At about the same time, Einstein was “buckling down” as he put it with the works of Lorentz, a physicist whose work would help Einstein see the nature of light in new ways and also help free him from the notion of the ether, though Lorentz was not trying to do away with the ether, only to change how it was conceptualized. Einstein was taken with Lorentz’s work, which would inspire much of the thinking in the special theory of relativity, but he was convinced that some of Lorentz’s approach was flawed. Yet Lorentz provided data which Einstein had been searching for, data which would help him prove or disprove the ether. Einstein was now on the road to becoming unshackled from the ether, a critical freedom he had to achieve in order to move onto higher ground toward his relativity theory.

In the period from 1901 to 1903, most of Einstein’s work in his learning problem could be considered slogging. He did a lot of exploratory and false-start writing. His aborted first dissertation, presented late in 1901, was withdrawn in 1902. He worked on a second dissertation starting in 1903. He struggled with the apparent gap in Lorentz’s theory, with an alternative emission theory that was essentially going nowhere, and with the dilemmas inherent in Planck’s radiation work. He was moving toward despair, and also deeply discouraged about unemployment and financial dependence on financially struggling parents who opposed his desired marriage to woman who was, in secret (but to his knowledge) giving birth and giving up their baby for adoption. He stumbled personally as he stumbled scientifically, still lacking a doctorate or standing in the scientific community besides a few minor papers.
But, as seems to be the nature of the difficult slogs of the interacting and persevering stage of a project, there was also forward motion that carried the seeds of future breakthrough. Einstein, with first one and then another man who had intellectual bents similar to his, established the Olympia Academy in 1903, a learning club of sorts. The men read Hume, Mach, Poincare, and other perspective-disturbing philosophers and scientists who would become major triggers, guides and sustainers during Einstein’s career. In these readings and provocative conversations, Einstein found the first stirrings of freedom from absolute time and space.

Einstein found himself on more solid footing personally in 1904, possessing a permanent (rather than the previously temporary) position at the Swiss Patent office, married, and the father of an infant son. On his learning project, he was working doggedly, with focus and long perseverance, but without much insight yet. He worked on an effort to use an emission light theory to replace Lorentz’s flawed version of Maxwell’s electromagnetism formula, but the necessary mathematical transformations eluded him. He kept working on other, more accessible projects though, and despite his humiliating failure to find academic employment he published his fifth scientific paper in 1904. The undercurrents of breakthrough were beginning to flow: he was starting to think about light in terms of a quantum theory.

Breaking Through: The Explosive Results of Extended Independent Learning

One of the fascinating aspects of investigating Einstein’s work as a breakthrough learner is that his early revolutionary breakthroughs occurred while he was an obscure and apparently unqualified scientist (Bernstein, 1999/2006). He had not been considered a brilliant student, had no doctoral degree, and was not even working as a scientist but as
a bottom rung technical clerk in a patent office. He was even delighted with that humble post after having failed long and miserably to find any position in science or mathematics—not teaching in college or high school, not even as a lowest level laboratory assistant, even failing at that last ditch effort for a job selling insurance. He had no family money to fall back on—his mother was recently widowed and working as a housekeeper—and he had felt growing shame over his dependence on his struggling family (Stachel et al., 1987). Profoundly transformative scientific brilliance would scarcely be expected from such a man or circumstance.

Einstein’s private scientific work was thus highly independent, supremely self-directed, and only more amazing in its unthinkable success in light of these unprivileged professional roots and lack of resources. That his success came not as a casual trickle or tentative buildup, but as a stunning explosion of creative breakthrough, makes the story seem all the more mythical. These breakthroughs began spilling out in early spring, 1905 with his first paper on relativity and four additional astounding theoretical papers. They flowed from Einstein’s dining room table at six to eight week intervals as, somehow finally prepared for breakthrough after years of formal and non-formal preparation, thought-experiment, and related learning behaviors which will be explored in this research, Einstein somehow cracked the code to one question after another, finally reaching hard-earned if swiftly achieved learning objectives that, in turn, stunned everyone (Einstein 1905i, j, k, r, s/1998a, b, c, d, e).

In addition to these groundbreakers, in the same year he published 21 reviews of other scientific works from German, English, French, and Italian sources, all on topics of thermodynamics. Except for a couple of follow-up reviews in coming years, this was the
only time Einstein would publish reviews of others’ work. But in 1905 this strenuous reviewing project immersed him in a broad spectrum of experimental findings and theoretical perspectives, all relating to the topics in which he produced his own field-transformative works in the same year (Einstein, 1905/1989, docs 6-13, 17-22, 25-31); see also Klein, Knox, & Schulmann, 1993; Miller, 2001; Stachel et al., 1989).

Einstein’s 1905 breakthrough year has come to be called the *annus mirabilis*, or miracle year (Gribbin & Gribbin, 2005). Together, “using totally unfamiliar kinds of reasoning,” Einstein’s major publications of 1905 declared that “essentially all of the physics [being taught was] wrong. Not just wrong in a few minor details, but fundamentally wrong” (Bernstein, 2006, p. 121). This miracle year represented “the most important package of ideas from any scientist since Isaac Newton” (Gribbin & Gribbin, p. 1).

Before Einstein, *annus mirabilis* was a common reference to Newton’s special year, 1665-1666, when the 24-year-old graduate student initiated his own great transformations of physics and mathematics by setting out theories of gravitation and optics (uncannily foreshadowing two of the major topics of 26-year-old Einstein’s big year two and a half centuries later), along with his rendering of calculus (Stachel, 1998). The term *annus mirabilis* actually originated with poet John Dryden’s “*Annus Mirabilis*: The Year of Wonders, 1666,” celebrating “the victory of the English fleet over the Dutch as well as the city of London’s survival of the Great Fire” (Stachel, p. 3), but not referencing Newton’s coinciding breakthrough contributions, which were not yet widely recognized and would not even be published until much later.
We can tell that Einstein’s fascination with his version of the universal question, “How does it all work?” took hold in childhood and carried him through his life. Yet it is interesting to consider here that one source of Einstein’s miracle year inspiration was probably a series of provocative questions laid out by a kindred spirit, a man who was both troubled and fascinated by a constellation of questions similar to those sharing space in Einstein’s own mind. Holt (2005/2006) describes the situation:

Einstein…had recently read a book [La Science et l’Hypothèse, 1902.] by Henri Poincaré, a French mathematician of enormous reputation, which identified three fundamental unsolved problems in science. The first concerned the “photoelectric effect”: how did ultraviolet light knock electrons off the surface of a piece of metal? The second concerned “Brownian motion”: why did pollen particles suspended in water move about in a random zigzag pattern? The third concerned the “luminiferous ether” that was supposed to fill all of space and serve as the medium through which light waves moved, the way sound waves move through air, or ocean waves through water: Why had experiments failed to detect the earth’s motion through this ether? Each of these problems had the potential to reveal what Einstein held to be the underlying simplicity of nature. Working alone, apart from the scientific community, the unknown junior clerk rapidly managed to dispatch all three. His solutions were presented in four papers, written in the months of March, April, May, and June of 1905. (p. 249; see also Miller, 2001; Rigden, 2005)

Poincaré’s three challenges (studied by the Olympia Academicians in 1904) and Einstein’s breakthroughs, “addressed a common theme, which was the nature of light and
its relation to the limits of physical theory” (Miller, 2001). Like Einstein, Poincaré “presented himself as a mind unbound” (Galison, 2003, p. 28). While some, including Galison, dispute the verifiability of Einstein having read Poincaré’s provocative questions before 1905, Poincaré did influence Einstein’s thinking throughout his career (Einstein, 1949).

As predicted by adult learning theory, such influences and opportunities shaped Einstein’s learning project from the start. Merriam, Caffarella, and Baumgartner (2007) point out that “adult learning does not occur in a vacuum. What one needs or wants to learn, what opportunities are available, the manner in which one learns—all are to a large extent determined by the society in which one lives” (p. 25). While Merriam et al., like many others in the field, are primarily concerned with the social aspects and opportunities of adult learning (perhaps, in part, because we place so much emphasis on defining the adults themselves by their social roles), we can substitute “resources, environment, and culture in which one lives” for “society in which one lives.” This substitution better reflects the situation of adults whose learning work is focused not so much on navigating and influencing social roles and mores, but on solving problems which have a different sort of impact. This broader view is in line with Darkenwald and Merriam’s (1982) encompassing definition of adult education as “systematic and sustained learning activities [by adults] for the purpose of bringing about changes in knowledge, attitudes, values, or skills.”

The first paper of the miracle year, on the photoelectric effect, introduced photons, as they were later called, as an essential element of light (Einstein 1998/1905i). This new perspective shifted optical science away from the idea that light behaved only
as a wave. Eventually this paper on the paradoxical behavior of light would win the Nobel Prize for Einstein. Not only did it set up questions about light which still engage contemporary physicists, it served as a scaffold for his and others’ further exploration of the subatomic frontier (Goldsmith & Bartusiak, 2006). The paper was the first famous result of Einstein’s independent learning project to effectively be the wing man for a light wave, ride along and all around it, and eventually understand its nature and how its motion could be understood.

Though this new theory did not capture the popular imagination as directly or as soon as his theories of relativity, the paper led to “the new laws of physics, quantum mechanical laws, the laws that are appropriate to atomic motion” (Feynman, 1999, p. 43). However, unlike Einstein’s singular claim to relativity theory, quantum physics would require a cadre of creative minds. Al-Khalili (2004) admits that “the discovery of quantum mechanics would have been simply too much for one person. Its development took thirty years and the combined intellectual might of the world’s greatest minds” (p. 30) (see also Lightman, 2000). Eventually, though, Einstein’s paradoxically behaving light would play into this entirely new branch of physics.

[The quantum revolution] completely changed the way in which we understand the nature of matter and radiation, giving us a picture of reality in which particles behave like waves and waves like particles, where our normal physical descriptions become subject to essential uncertainties, and where individual objects can manifest themselves in several places at the same time. (Penrose, 1998, p. vii)
Einstein, to the end independent and true to his own curiosity and sensibilities as a learner, would eventually take his learning project in other directions. The disorderly and outrageous nature of quantum mechanics was not for him. However, as an outgrowth of this first fabulous breakthrough, it transformed the last century and continues to drive the science and technology of the new one.

The next two papers of the miracle year validated the idea of atoms and theorized on their size and motion (in this case, Brownian motion). Brown, a Scottish botanist, in 1827 observed that particles of pollen grains suspended in liquid were moving about independently from water currents or any other apparent cause. Every other type of molecule he then studied exhibited this random, jiggling motion. The explanation for this motion, it turns out, is the thermal effects which cause molecular motion inside the water in which the bits of dancing matter are suspended. Einstein provided a major advance in theory when he developed an atomic explanation of Brownian motion, and applied statistical mathematics to approximate the number and size of suspended molecules per cubic centimeter of liquid (Moring, 2004).

Not only did Einstein explain the motion of molecules, he proved their existence, a proof the necessity of which seems odd to the contemporary thinker. “It is difficult to imagine the suspicion and hostility at the end of the last century to the idea that atoms existed,” agree Hey & Walters (1997, p. 106). While the idea of atoms goes back to Greeks of the fifth century B.C., and Newton posited movable particles as God’s building block of matter, it was difficult to examine such miniscule bits of matter by experiment. Further, nineteenth century thermodynamic theory seemed to conflict with the concept of atoms, since atomic theory described the properties of matter as the reversible
consequence of colliding atoms, the reversibility of which could not yet be reconciled with the apparently one-directional force of entropy. Nor could thermodynamicists then square their work with Brownian motion, since these movements suggested the feasibility of perpetual motion, another idea flying in the face of their theories about one-way effects of time (Hey & Walters).

Einstein’s specific predictions about atoms were eventually confirmed by experiments. Hey & Walters (1997) report on the implications:

Along with the discovery of the electron in 1897, [these confirmations] were enough to convince even hardened atomic skeptics such as Ostwald, who, in 1908, conceded that the results “entitle even the cautious scientist to speak of an experimental proof for the atomistic constitution of space-filled matter.” (p. 112)

However, the winning over of atomic theory skeptics came too late to save the career and life of a trail-blazing physicist whose work inspired Einstein. Ludwig Boltzmann, a Viennese physicist, was this atomicist. He acted as one of several models and resources who fed Einstein’s learning project. Einstein had begun studying Boltzmann’s work by 1899 (Einstein, 1899/1987, Doc. 54), finding it stimulating. Einstein gave this glowing report to his classmate (and future wife):

The Boltzmann is magnificent. I have almost finished it. He is a masterly expounder. I am firmly convinced that the principles of the theory are right, which means that I am convinced that in the case of gases we are really dealing with discrete mass points of definite finite size, which are moving according to certain conditions. (Einstein, 1900/1987, Beck English translation, doc. 75, p.149)
Boltzmann’s work included determining the important statistical definition of the second law of thermodynamics, or the law of entropy (Feuer, 1974). But, scorned by the opposition to his work in atomic theory, he took his own life in 1906, when Einstein’s miracle year had barely begun the slow process of turning the tide toward acceptance of Boltzmann’s “bold and far-reaching” (Feuer, p. 335) work. Eventually, the conflicting issues of thermodynamics and atomicism were resolved probabilistically, with the understanding that the strange effects (including the reversibility of events occurring over time and the plausibility of perpetual motion) were so statistically unlikely that “we would have to wait for a time much longer than the present age of the universe” to hope to see these outcomes (Hey & Walters, 1997, p. 112).

If these first three papers of the miracle year were triggered in part by Poincaré’s articulation of three challenge problems, the dazzling fourth paper had a more poignant provenance. The special theory of relativity (and the footnote-like fifth 1905 publication a few months later, debuting a thrilling new equation, \(E=mc^2\)) stemmed from a boyish longing to know God, and a young man’s wanton confidence that he could do so. Lightman (1993) dramatizes one of the significant strolls Einstein took with his old friend from college, Swiss patent office colleague, and cherished sounding board, Michele Besso:

Einstein leans over to Besso, who is also short, and says “I want to understand time because I want to get close to The Old One.” Besso nods in accord. But there are problems, which Besso points out. For one, perhaps The Old One is not interested in getting close to his creations, intelligent or not. For another, it is not obvious that knowledge is closeness. For yet another, this time project could be
too big for a twenty-six-year-old. On the other hand, Besso thinks that his friend might be capable of anything…. Ever since Besso has known him, Einstein has been self-sufficient…. Like Besso, he is married, but he hardly goes anywhere with his wife. Even at home, he sneaks away from Mileva in the middle of the night and goes to the kitchen to calculate long pages of equations, which he shows Besso the next day at the office.

Besso eyes his friend curiously. For such a recluse and an introvert, this passion for closeness seems odd. (pp. 52-53, 54)

That paradoxical passion for closeness and isolation, devotion to his quest for an intellectual-spiritual connection and striking inattention to many social ties, would come to define much of Einstein’s life and work.

Shortly after this stroll, on a spring day while at work at the patent office, Einstein and Besso held a major brainstorming session about this “cosmic jigsaw puzzle” (Brian, 1996, p. 60). This was the day that Einstein, who had struggled in vain on the same conceptual treadmill for a year, told Besso he was ready to give it up. He had no way to proceed.

Besso talked through the whole learning problem with him. The more they worked with the problem, the more impossible the task seemed. Einstein “returned home in despair, feeling he would never discover [the answers]” (Brian, p. 60). But Einstein woke up the next morning as “‘a storm broke loose in my mind,’ [and] with it came the answers. [Einstein] had finally tapped ‘God’s thoughts’ and tuned in to the master plan for the universe” (p. 61). The miracle year had reached its climax.

And he was just getting started. For the next decade he worked independently and intensively, with limited assistance from a few chosen colleagues who set him on the right path in higher mathematics, as he developed and articulated the transformational general theory of relativity.

At age twenty-six, Einstein’s decade-long, self-directed mission to understand light as it moves through space ended in a storm of ideas. The resulting theory brought to a climax a chain of revolutions that transformed humanity’s place in the cosmic arena. The history of physics, and before that the natural philosophy that served as early science, is punctuated by this succession of theories and observations that first threatened, and finally, with Einstein’s project, crushed, some fundamental principles of established philosophy and theology, and disoriented anyone who looked thoughtfully at the night sky.

This matter of relative motion is the heart of the special theory, and is its boundary. It was the problem that had to be overcome to finally conceptualize a general theory of relativity that worked for any frame of reference. In 1928, Einstein related the dilemma in his response to a young student’s letter about relativity:

Motion can be experienced and presented by us only as relative motion…. [Previously] it was thought that the concept of absolute motion was necessary for the formulation of the laws of motion. To disprove this became an
obstacle in relativity theory. Your question asking what the world would be like if only one body were in it cannot be answered with certainty today, because we don’t know if there could be space around that body. But we do know for sure that it is meaningless to speak of its motion. (Einstein, 1928/2002, pp. 119-120)

Yet, for all of the mental gymnastics these ideas may require, it is possible to consider the rudiments of the relativity problem with a simple visualization. This one sets up the kind of visual thought-work that defined Einstein’s early learning endeavors, and which will be considered at length in the course of this project.

Imagine you are standing at a train station and see a train speed by. Compared with you, or relative to you, the train is going very fast. Now, imagine you are in a car moving in the same direction and at the same speed as the train. Relative to you, the train is standing still. That’s relativity! (Berger & Berger, 2007, p. 23)

Addressing the effects of mass and energy on relative time, Epstein (1997) describes the relationship in logical progression:

Gravity makes time run slow. Mass makes gravity. Mass makes time go slow. So near masses, time runs slower than it does in parts of space away from mass. Your feet age more slowly than your head! How slow can it go? If you have enough mass, you can make time stand still [thus, a black hole]. If time goes slow, everything goes slow—even light. That explains why light goes slow near mass…So, if you like, you can make light go slow without changing the speed of light. You change the speed of time. (p. 500)

Light speed, the third component of the famous equation (the other two being energy and mass), is a sort of acceleration governor for the universe. “Physicists are
obsessed with the idea,” reveals Magueijo (2005, p. 78), and $c$, the notation for the speed of light, has become “the reliable and certain pillar of modern physics, a safe haven where the physicist may attempt to define rigidity in a world rife with variation” (p. 78), an allure much like Einstein’s described attraction of mathematics itself, which “above all other sciences, [has laws which are] absolutely certain and indisputable, while those of all other sciences are to some extent debatable and in constant danger of being overthrown by newly discovered facts” (Einstein, 1921/2006, para. 2). Math was not his greatest strength, though, and he would need to stretch and to enlist colleagues as learning resources to help him acquire the advanced competencies he needed to explore his questions beyond the special theory (Brian, 1996; Clark, 1971; Isaacson, 2007). The math he used to frame the special theory was, by the standards of physics, relatively basic. Still, representing the notion that light speed appears the same for all observers, Einstein was able to show that:

Nothing could be moving faster than light. What happens is that as one uses energy to accelerate anything, whether a particle or a spaceship, its mass increases, making it harder to accelerate it further. To accelerate a particle to the speed of light would be impossible because it would take an infinite amount of energy. (Hawking, 2001/2005, p. 45)

Thus, with one theory, Einstein not only broke out of his own frustrated obscurity, he shook apart the world’s fundamental notions of “absolute space, absolute time, and absolute velocity” (Bachelard, 1905, p. 567). However, these concepts are fundamental elements in human thought systems. Freidman & Donley (1985) explain:
The idea of a universal present is so important that it should be afforded the status of a myth. Deeply ingrained in Western world views had been the concept of time flowing uniformly all over the universe. The state of that universe could be known, at least to God, as it changed from instant to instant. But now the ‘universe as a whole’ has been separated into fragments that can never share a universal moment of time. Even the ‘moment of creation’ could not exist, unless the creation of the universe happened at a single point in space [thus, the big bang]. (p. 57)

Further reshaping our understanding of mass and gravity, Einstein showed that the background against which we still perceive our things and experiences (fixed space and time) is actually something of an illusion. First he revealed, in the 1905 special theory of relativity, that the real background of the universe is an integrated fabric called space-time. Then, with the general theory of relativity, the illusion of distinct space and time was shattered completely. General relativity describes the space-time fabric as not purely a background but a shapely, malleable, interactive element of our experience. Minkowski (1952/1923) declared that “henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality” (p. 75). Einstein (1961) later made a further distinction, saying:

Space-time is not necessarily something to which one can ascribe a separate existence, independently of the actual objects of physical reality. Physical objects are not in space, but these objects are spatially extended. In this way the concept “empty space” loses its meaning. (p. vii).
Setting space-time in motion, in a dance with matter, revolutionized our understanding of gravity and the integral workings of the universe:

Einstein’s original [1905] theory of relativity….shows that…future and past are just directions, like up and down…in something called space-time…. [With] the general theory of relativity in 1915….space-time is not flat, but is curved by the matter and energy in it. This was Einstein’s greatest triumph…. [Space and time] were now dynamic quantities that influenced and were influenced by events that took place in them. (Hawking, 1993/2006, pp. 202-203)

Einstein transformed our understanding and perspectives in many ways. “Like Copernicus before him… Einstein astonished his contemporaries with entirely new ways of looking at [these] phenomena that had been known for decades, or even centuries” (Gingerich, 1979/2006, p. 25). He dared to leave behind much of what was then known about the physical world in order to satisfy questions that had come to define his life.

Einstein clearly did not take the safe route in his learning projects, at least not with his early work that led to these theories of relativity. He followed a path of wonder and uncompromising curiosity, which may have been his chief motivation and direction for learning (though motivation for independent learning projects of Einstein magnitude is necessarily more complex than a single variable, and deserves considerable attention in this project). In Einstein’s words, “The most beautiful thing we can experience is the mysterious—the knowledge of the existence of something unfathomable to us, the manifestation of the most profound reason coupled with the most brilliant beauty” (Einstein, 2007, p. 58). Einstein was not one to sit still with the unfathomable, though, but took it into his arms to see what he could learn. Bodanis (2000) reflects that
Einstein’s “goal, as always, was simply to see what had been intended for our universe by The Old One” (p. 217).
CHAPTER VII

THE GENERAL THEORY OF RELATIVITY AND THE QUINTESSENCE ADULT LEARNER

God gave me the stubbornness of a mule and a fairly keen scent.

– Einstein

Breaking Through: Regrouping and Extending the Learning to General Relativity

Einstein knew when he finished his special relativity theory that he was not finished. For one thing, his mind and visions ran to fundamental, all-encompassing principles, which the special relativity theory was not. Einstein wanted to make sense of everything, not string together bits and pieces. Also, he had connected strongly with the writings of Ernst Mach, philosopher and physicist, a man who espoused ideas that either echoed Einstein’s own possibly less-articulate views, or settled in satisfying and promising ways into the constructs and instincts Einstein already held—and he was a young man of strong instincts and prejudices about philosophy and intuition about physics. Mach was not a fan of special cases any more than was Einstein, and Einstein was motivated to keep his work in line with what he felt were the expectations of his book-bound mentor.

It was with a mixture of sensed victory and incompleteness that Einstein emerged from his miracle year. In this context he began to incubate the general relativity theory, not really knowing how to move past the special theory but believing that he must. He used a few obvious strategies to extend his relativity formulas, but every attempt conflicted with Newton’s law of inertia. Still, he was determined to extend relativity to all reference frames. But having hit a wall for now, he put his primary focus on other
projects. He continued working at the Patent Office, and submitted six more papers for publication in 1906 and again in 1907 before he came to a new defining point in the project.

Late in 1907, a publisher asked Einstein to write an article on relativity to review the special theory and its applications in physics. In the previous couple of years other physicists had begun to take an interest in Einstein’s special theory and a few had begun to do their own follow up research. Now Einstein needed to step back and look at his work, the way others were thinking about it, and how the major areas of physics were impacted by the theory.

This was, it turned out, another opportunity for Einstein to do one of his “I am stuck” full project reviews. Whether or not Einstein ever realized and appreciated this pattern in his learning, or ever used it in an intentional way as a breakthrough insight trigger, this was a magical configuration for him, consisting of being stuck, stepping back, doing a full review (preferably intended for someone else to hear, share, or read), going into the transformative attention mode of incubation activities that access the spontaneous pathway (like sleeping, daydreaming, playing music, or walking), and finally reaping the rewards of creative insight.

Two special insights came from this review. The first, a critical one, came as he noticed that he could talk about relativity in terms of most areas of physics, but not with regard to gravity. Whereas studying the works of others often led Einstein to notice gaps, paradoxes, or pieces that did not fit as the author seemed to think they did, Einstein was able in this case to find a fertile gap by studying his own work. He decided that gravitation really should be addressed by relativity. Of course he would accept the
challenge of the gap, being an admirer of all-encompassing ideas. But he was also guided by his earlier reading of Mach, who believed that all gravitational theories should be relational theories. Adopting this principle, and others, from Mach helped guide him toward his general relativity theory, though his strict adherence, or misinterpretation, sometimes led him astray.

The other insight from this process of applying transformative attention was even grander. Daydreaming at his desk, during the period in which he was writing or had recently written this review article, Einstein experienced the image of a man in freefall, and noticed, following this thought, that the fact that this man would not feel his own weight while in descent was an idea with profound implications that had never before occurred to him.

Einstein’s fresh insight was about a uniform gravitational field (the area in which a man is falling from a roof, on earth) being essentially the same thing, in terms of the relevance of the laws of physics, as an accelerating frame of reference (riding in a space ship). This idea, known as the equivalence principle, makes inertial mass and gravitational mass equivalent.

Inertia is an object’s resistance to changes in momentum. In other words, it is the tendency to maintain a momentum until something else interacts with it. Inertial mass, then, is a measure of how much acceleration results from an amount of force applied to an object. This is easier to understand in a thought experiment.

Place a bowling ball and a marble side by side on a bowling lane. Now push the bowling ball and marble at the same time with a given amount of force. Of course the marble will shoot down the bowling lane much faster (issues of friction aside) than the
bowling ball. This is a way of saying that the marble has a different inertial mass than has the bowling ball. Applying force to the stationary marble has a different effect than interacting with the stationary bowling ball, though they are both in the same state (stationary) and experience the same outside pressure.

The bowling ball also has greater gravitational mass than the marble. The bowling ball exerts a greater gravitational pull on the marble than the marble exerts on the bowling ball, though both gravitational effects are of course far too small for us to notice, influenced as we are by the far more powerful gravity of the earth. If we trade the bowling ball for the earth, though, and the marble for the moon, the gravitational mass differences become obvious as we see which body pulls the other into orbit.

It happens that when scientists measure the inertial mass of the bowling ball and marble (the shooting-down-the-lane effect after being pushed) they get the same result as when they measure the gravitational mass of those objects. The only difference is how the measurement is taken and the force description it implies. Inertial mass describes acceleration that results from force—the speed of the ball or marble down the lane. Gravitational mass describes the apparent pulling force of one mass relative to the other, or the relative attraction power of the bowling ball and marble, or the earth and moon.

The measurement of the acceleration effect of a push on the bowling ball and the measurement of its apparent pulling power relative to the marble are the same number. Mass is mass, and however we look at it, it describes power, or power’s effect, or the ability to resist power (resisting changes in momentum).

This law of the equivalence of inertial and gravitational mass was Galileo’s and Newton’s idea. In the late 16th century, Galileo noticed the curious coincidence of the two
measurements being the same during experiments. In the late 17\textsuperscript{th} century, Newton extended the idea of equivalent measurements, and effected the paradigm transformation that was Newton’s theory of gravity. Newton’s theory explicitly called inertial and gravitational masses identical.

Einstein’s flash of insight, from the image of the man in freefall, was that the equivalence principle really implies that a man in freefall is not really accelerating. But in fact, he cannot tell, from the laws of physics, whether he feels weightless because he is falling or because he is accelerating, as on a spaceship. The freefalling man is inertial, or in a stable frame of motion, just as the stationary bowling ball and marble are inertial when sitting on the bowling lane.

Einstein could now say that with respect to falling bodies, we cannot tell the difference between a region with gravity and a region without gravity, as odd as that sounds. Later, he would decide that this observation is true whether or not there are any falling bodies, so that no type of physics measurement could determine if we are in a gravity field or accelerating. This is Einstein’s paradigm shift on the equivalence principle, and it became the foundation for the development of his relativistic gravitational theory based on space-time curving around mass and energy, causing gravitational effects on less massive objects in the region.

When Einstein made this explanatory-rich connection during his moment of insight, his project achieved a focus that gave him a place to start working, and something to start working toward, though the journey would be long and traumatic. Referring later to this breakthrough moment, he called it the happiest thought of his life. It certainly resulted in a scientific achievement that would be deeply fulfilling for
Einstein, that would shape his views of his work and of science forward-looking and backward, and that would be one of the most impactful paradigm transformations in the history of science.

For the next couple of years Einstein noodled on his gravitational theory. He had his great insight, his equivalence principle, but it was hard to know to proceed from there. What kind of object could make a gravitational field in a stationary frame of reference, or in other words equal a situation of acceleration? The search for this answer was critical, as it would give a model with which to work toward understanding relativity and gravitation in the fuller sense.

While he worked on this problem in the background, Einstein worked on other compelling projects that he felt were more approachable, like quantum theory and statistical mechanics, for which he was enjoying a growing reputation, enough so that he tried once more to break into academia. He tried for a teaching job, essentially as a moonlighting freelance lecturer, at the University of Bern, and eventually got the position, which simply added to his work load and did little for his bank account or professional standing. Still, the lack of footing on the relativity problem troubled him, and attached though he was to his equivalence principle, he was less than sure about building the full theory on it.

Late 1909 to 1910 brought new light and momentum to the relativity project, thanks to ideas coming in from other physicists. (Much as the Wright brothers often moved between major learning project stages as a result of breakthrough ideas or new data elsewhere in the field, Einstein’s project often turned corners when outside ideas or data brought new tools, angles, or strategies to bear on the problem.) Einstein began to
take risks with new ideas that he was quite unsure about, including Max Born’s ideas about the kinds of motion a body may achieve under conditions of special relativity, and Hermann Minkowski’s work on the geometry of space-time.

Engaging with these disorienting ideas, Einstein moved gradually toward finding the model of gravitational fields he was looking for, and toward a mathematical toolset with which to do understand it. Both tasks required considerable perseverance. Einstein called the rigidly rotating body, a potential model for the gravitational theory work, the “child of sorrow” (Stachel, 2002b, p. 268). Around the same time, though, he was finally making some career progress. In late 1909, he was able to resign from the Patent Office and take a position as professor at the University of Zurich, more than four years after the publication of his landmark works of the miracle year.

Finally, in 1911, six years after publishing the special relativity theory, Einstein was ready to grab the reigns of the general relativity project, working on the project in the forefront, with confidence, though he still had an exceptionally rocky four years ahead of him. Having finally accepted, and understood well enough, the model of a rigidly rotating body for his gravitation work, he seemed to feel confident enough to take on general relativity as his major project. He was also effecting a shift from dismissing Minkowski’s four-dimensional model of Einstein’s special relativity theory to studying and embracing Minkowski’s geometric model. As a result, an important new perspective emerged: a curved, rather than Minkowski’s flat, model would be needed for this model of gravity. Integrating some of these perspective transformations, Einstein published an article on the rotating disk as a gravitational field, and concluded that space-time was curved.
Finally, after mastering Minkowski’s four-dimensional approach, he corresponded with a colleague about the number of vectors associated with a gravitation field. The colleague made a comment about variable light speed and gravitational fields. That comment seemed to trigger another productive new direction for the project, as Einstein in short order moved with the variable light speed idea. He used the idea significantly beyond the context in which his colleague had offered it. Einstein adopted this controversial variable light speed to stand for gravitational potential within the framework of his emerging gravitational model. This shift forward was an important step toward finding the right field equations to stand for gravitational strength, an imperative step in the project before Einstein fully turned to a new geometric perspective of gravity.

Still moving in the stepwise fashion that characterized much of Einstein’s general relativity project, one barely achievable problem after another envisioned and solved, he completed his work on the static gravitational field (thanks to the variable speed of light insight) and was quite satisfied with his progress at that point, having behind him a stage in which he had described every step as devilishly difficult. The new challenge ahead, though, was to figure out how to work mathematically with the non-linear nature of the emerging geometric picture of space-time and gravitation. He was going to have to give up the mathematical form, called scalar equations, which he had been using fairly comfortably.

At this point, in 1912, Einstein was back in Zurich, teaching at his alma mater, the technical college which had graduated him and then declined to hire him. He taught analytical mechanics and thermodynamics, and a physics seminar. One of his colleagues was Marcel Grossmann, a college friend who had become a professor of mathematics.
When Einstein went to Grossmann with his requirements for a mathematical form in which to develop a non-linear multi-dimensional curved geometrical model, Grossmann agreed to help.

Grossmann’s search turned up a recently developed mathematics called tensor calculus which seemed suited to the task, and Einstein and Grossmann soon co-authored an article in which Einstein laid out his latest understanding of the relativity project, including his perspective shift from trying to understand and represent the rotating disk model and gravitation with standard Euclidean geometry to realizing that Euclidean geometry was the limiting factor in the problem.

In parallel with the struggle to realize that a new mathematical perspective on the problem was required, Einstein dealt with a more repellent perspective shift. Consistently one to want to understand physical reality in ways that did not belie both his intuitive and common sense about the physical world, he faced the challenge that space-time coordinates did not seem to have a corresponding direct physical interpretation. This was a persistently disorienting and perplexing problem for him. But, in his most recent article on gravitation, he reported in a tentative tone his finding of a case in which coordinates lack physical meaning. However, he was not yet ready for a full integration of this perspective shift. “It is not so easy,” Einstein said, “to free oneself from the idea that coordinates must have a direct metric significance” (1979/1949, p. 63).

Next up were two years of wandering in the wilderness. Einstein had gone into the use of the new mathematical tools with a strong belief in a necessary condition called general covariance, which meant that physical laws would have the same expression in
every system of coordinates. General covariance is a characteristic of the metric tensor calculus that Grossmann and Einstein had seized on.

But over a period of time, the generally covariant approach was not working out. Einstein tried out other approaches, temporarily at first. Then he changed his perspective more affirmatively by declaring that generally covariant forms would not work for the gravitational model. Now he believed, mistakenly as it would turn out, that general covariance implied an irreconcilable paradox when applied to a particular condition of space outside gravitational fields. And so Einstein gave up, with both disappointment and determination, an approach that seemed physically correct to him, and proceeded down alternate trails for many long and essentially fruitless months.

The holy grail at the heart of this horrible slog was a set of field equations which would describe how sources of gravity generate their gravitational fields. The generally covariant mathematics tools were, at first, supposed to light the way, but they were given up. Yet no alternative approaches were helpful in this quest.

While Einstein was enduring a partly self-made and most unpleasant roller coaster of a learning experience during this slog time, he was also in endurance mode in his personal life. His troubled marriage was ending in separation, leading later to divorce. Germany had entered World War I, and just about everything in his life including his learning project seemed, once again, simultaneously untethered.

But once again a productive breakthrough-producing strategy worked to part the curtains and bring the object of the quest once more into view. Two years of failure disoriented him to the point of pulling back, in late 1915, and reviewing the whole
problem from scratch. He gained perspective on the problems, and found the mistake in
his reasoning which had caused him to reject general covariance.

With a glad heart he snatched back the generally covariant geometry, made small
changes in the equations he had been working with (creating in the process the now-
famous Einstein tensor equation), and generating results which matched with empirical
data in such a way that an important step in validation was immediately achieved.
Einstein wrote to his dear friend Besso, “My wildest dreams have been fulfilled. General
covariance. The perihelion motion of Mercury wonderfully exact….This time the most
obvious thing was the correct one” (Stachel, 1989, p. 322).

Legacy of the General Relativity Theory

The implications of the (1915) general theory of relativity continue to propel
scientific investigation today. This theory applied not just to observers in motion relative
to each other, as did the special theory. The general theory took Einstein’s own
conceptualization of space-time and extended it into a transformative new understanding
of gravity as a mass-and-energy-driven distortion of the space-time fabric.

The general theory of relativity has innumerable applications today, but one of the
most common explanatory examples involves, not surprisingly, astronauts. In the space
shuttle, they are about one hundred miles above the earth, and despite common
perceptions they are not at all free of the gravity pull of the earth. In fact it is reduced by
only five percent. The astronauts and any of their untethered gear will certainly float
around the shuttle while on orbit, but not because of freedom from gravity. They float
because they and their spacecraft are falling together toward the earth, and falling
constantly, while staying in orbit (Zee, 2006).
The astronauts and their craft stay in orbit, rather than plummeting to the ground, because they are moving fast enough around the earth that their falling keeps pace with the falling away (as all bodies in space are in motion) of the earth. Because they are falling, the astronauts do not perceive gravity. This is the insight Einstein had in 1907, leading to the general theory of relativity: A person freely falling will not feel his own weight. Zee says that “From this apparently nonsensical idea…emerged the secrets of gravity and the universe” (2006, p. 224). Wheeler (1990/2006) explains further:

Only by understanding gravity as grip of spacetime on mass, and mass on spacetime, can we comprehend even the first thing about the machinery of the world—the inertia of a particle, the motion of the planets, the constitution of a star. Without a grasp on gravity, we would not perceive the link between the fall of the nearest pebble, the orbit of Europa, the beelike buzzing of a star cluster, the two hundred million years of each tour of the Earth about the Milky Way, and the fantastic power output of the distant quasars. (p. 213)

Even more fundamentally, general relativity “describes how our universe was born, how it expands, and what its future will be” (Dressler, quoted in Bartusiak, 2006, p. 319). Elsa Einstein, Albert’s second wife, visiting the Mount Wilson observatory in California with her husband, was told that the great telescope “was used to determine the universe’s shape, to which she reportedly replied, ‘Well, my husband does that on the back of an old envelope’” (Bartusiak, 2006, p. 319), which was, in fact, the case.

The field of cosmology was fathered by the general theory of relativity. Einstein, significantly driven by his continued reliance on Mach’s precepts about the necessary states of physical reality, was disconcerted when colleagues quickly found instances for
which the general theory of relativity yielded uncomfortable results, from a Machian perspective, for experimental models. Einstein worked his way around this problem, and, in his mind, concluded the full search to understand relativity, by developing a static cosmology, or closed universe, which neither expands nor contracts. While the static nature was disproven and Einstein finally gave it up himself, perhaps not coincidentally after having released his grip on Mach’s views, the process of constructing this first cosmology, and some elements of the theory itself, proved to be foundational for future work in this area.

Kolb (2006) reports that “we cannot even address the basic questions of modern cosmology without [general relativity]. Modern cosmology began shortly after its unveiling; in fact, the first paper on modern cosmology was written by Einstein, himself, in 1917” (p. 203). In that paper, Einstein described the cosmological constant, “the outrageous idea that empty space has a mass-energy density—a sort of ‘weight of space.’” (Kolb, p. 203). With uncanny prescience, “Einstein invented dark energy in the form of a cosmological constant to keep the universe unchanging over time. He would likely appreciate that dark energy can also play the central role in keeping the universe cycling” (Steinhardt, 2006, p. 251). (Dark energy is a recently developed but widely accepted theoretical construction which explains the increasing rate of expansion of the universe.)

Following on Einstein’s work, cosmologists continue to construct strange and fascinating visions of the past, future, and shape of the universe. While space and time in a Euclidean view (based on three-dimensional space) apparently extend infinitely forward and back, cosmologists can use relativity to work with models that close together the
ends of either space or time, or both, or in other ways reconfigure how space-time might be viewed. These gyrations are based on assumptions about the effects of mass, and other influencers, on the possible curvatures of space-time (Epstein, 2000).

Yet, for all of his fantastic insights, Einstein’s vision was not perfectly clear. The general theory of relativity implied that the universe must always be in state of contraction or expansion (Goldsmith & Bartusiak, 2006), a fundamental principle in our understanding of the universe. However, as described earlier, Einstein did not recognize or accept this natural corollary of a universe in motion until it was measured by Hubble some years later. Bartusiak (2006) explains:

At the time, astronomers conceived of the universe as a large collection of stars fixed forever in the void. Einstein accepted this immutable cosmos. Truth be told, he liked it. Einstein was often leery of the most radical consequences of his ideas. (p. 321)

Einstein’s reluctance, in maturity, to step into some of the more revolutionary suggestions of his own work (from his slowness to catch on to the expanding universe to his adamant rejection of the bizarre implications of his own work in quantum theory) is interesting in light of the youthful ease with which he stripped away one fundamental after another of classical physics in order to answer his simple but seemingly impenetrable questions about how things worked. Indeed, Gamow (1985/1966) reflects that:

It usually happens that the most important work of a theoretical physicist is done at the age of about twenty-five, when he has had time to learn enough of the
existing theories but while his mind is still agile enough to conceive new, bold
revolutionary ideas. (p. 19)

Like Newton and Einstein, Niels Bohr published his major work on atomic
structure at twenty-seven, and Werner Heisenberg co-published the matrix formulation of
quantum mechanics at twenty-four. But there are exceptions, as in Max Planck whose
“real outburst in his scientific work” (Gamow, 1985/1966, p. 19) in quantum physics
came at age forty-two. These paradoxes of conceptual immobility and obstacles to
visionary breakthrough are apparent in the work of the last half of Einstein’s career.

The Smallest and the Greatest: Quantum Theory to Unified Field Theory

The creative mind is a restless, stretching mind. The sometimes brilliant outcomes
may lead to uncomfortable positions. In his *Autobiographical Notes*, Einstein mused:

Newton, forgive me; you found just about the only way possible in your age for a
man of highest reasoning and creative power. The concepts that you created are
even today still guiding our thinking in physics, although we now know that they
will have to be replaced by others farther removed from the sphere of immediate
experience, if we aim at a profounder understanding of relationships. (1979/1949,
p. 31)

Einstein continually moved toward the larger questions posed by his latest
solutions (Kaku, 2004). His work prepared him to tackle ever more complex
conceptualizations, and he applied himself to what he felt were the most important
problems he could tackle. Though he contributed to theory in physics from a variety of
perspectives in the latter half of his career, and sometimes collaborated with other
scientists to come up with advances like a new explanation of magnetization (Anderson,
Einstein’s last grand quest was for what is known today as an integrated theory of everything. In Einstein’s day, this was the search for the unified field theory. Kaku, a contemporary theoretical physicist and cosmologist, describes the goal:

[Einstein worked to] unify his theory of gravity with Maxwell’s theory of electromagnetism. It was supposed to be his masterpiece, as well as the summation of science’s two-thousand-year investigation into the nature of gravity and light. It would give him the ability to “read the Mind of God….” (p. 147)

Boorstin (1998) acknowledges this transcendental motivation. He notes that “to find the whole explained by law and reason inspired what [Einstein] called his ‘cosmic religious feeling,’” and this pursuit of unity became “his lifework. His was the modern search for meaning” (p. 251).

“The problem facing Einstein now was truly daunting,” continues Kaku (p. 150), “because he was working at least fifty years ahead of his time.” The next generation of scientists would benefit from knowledge developed in that period, garnering increasing success for a final theory (Weinberg, 1992). Weinberg (2005) notes that this is an expected focus for a great physicist:

The greatest advances in the history of physics have been marked by the discovery of theories that gave a unified explanation of phenomena that had previously seemed unrelated….Newton had unified celestial and terrestrial physics….[and] Maxwell had [recently] unified the phenomena of electricity and magnetism. (p. 102)

Einstein felt confident that he could finish the job.
Before thoroughly immersing himself in work on the grand unified theory, Einstein contributed foundational work for quantum theory in two key phases. Though “he was extremely circumspect in mixing quantum and relativistic considerations” in his Nobel Prize winning (1905) paper discussing the quantization of light (Stachel, 2000, p. 240), that paper unquestionably belonged to the period of quantum theory, along with seminal papers by Born, Planck, and Bohr, and another series of quanta-related papers written by Einstein right after he completed his general theory of relativity (Robinson, 2005). This early period of quantum theory would soon be supplanted by the even more outrageous, and still current, era of quantum mechanics.

The final flurry of Einstein’s papers on the subject marked “the end of the ‘old’ quantum theory and the beginning of quantum mechanics. It was also the end of Einstein’s central role in quantum physics; after 1926 he became a critic of, rather than a contributor to, the theory” (Robinson, pp. 91-92). Nevertheless, his criticisms furthered the progress of quantum mechanics. Bohr reflected that “were it not for Einstein’s challenge, the development of quantum physics would have been much slower” (Robinson, p. 92). Additionally, notes Zeilinger (2006, p. 124), “the issues he raised gave rise to many experiments that are laying the basis for a new information technology that entails concepts such as quantum cryptography, quantum teleportation, and the quantum computer.”

Einstein required an orderly universe, but quantum theory threatened this order even in the early days when Einstein still contributed to the work. As it became quantum mechanics, a vista of uncertainties, probabilities and fantastic paradoxes unfolded, and Einstein broke rank (Overbye, 2005/2006). Quantum physics continues to be a
controversial field today, conspicuous in part for the diversity of perspectives and interpretations that are adopted to attempt to make sense of what remains insensible (Al Khalili, 2004; Sternheim & Kane, 1991). Nonetheless, quantum mechanics and its strange propositions are now widely accepted. Penrose (1998) declared that both relativity and quantum mechanics “have now been observationally confirmed to a precision unprecedented in scientific history” (p. vii), as is illustrated in the case of a 2005 experiment in which beryllium atoms were sent spinning both clockwise and counterclockwise—at the same time (Overbye).

This quantum weirdness has useful applications which have defined the technological revolution of our day. From our new understanding of molecular behavior we now enjoy digital media, fiber optic cables, television cameras, lasers, solid-state devices, power generators, photoelectric cells, critical pharmaceutical production processes, and much more (Goldsmith & Bartusiak, 2006; Holton, 1982/2006). And of course we also gained a number of now iconic science fiction effects, such as teleportation, which stems from what Einstein called the quantum world’s “spooky action at a distance” (Ottaviania & Langridge, 2006, p. 236; see also Overbye, 2005/2006).

However, the science fiction moniker for this and other formerly fictive quantum phenomena is being challenged by recent laboratory advances, including experiments in which scientists have actually teleported fragments of information, levitated bits of gold above a glass plate, and developed materials that could lead to the production of an invisibility cloak (Dowling, 2009).

Feigenbaum, a pioneering physicist in chaos theory, describes the implications of quantum mechanics this way:
It tells you how you can take dirt and make computers from it. It’s the way we’ve learned to manipulate our universe. It’s the way chemicals are made and plastics and what not. One knows how to compute with it. It’s an extravagantly good theory—except at some level it doesn’t make good sense….In the end it’s so far out of your normal way of picturing things that you run into all sorts of conflicts. Now maybe that’s the way the world really is. But you don’t really know that there isn’t another way of assembling all this information that doesn’t demand so radical a departure from the way in which you intuit things. (Gleick, 1987, pp. 184-185)

Thus, Feigenbaum echoes some of the discomfort Einstein felt with the weird effects of the theory. Einstein broke away from the mainstream of work in quantum physics when he could not accept the probabilistic implications recognized by most of his colleagues. He disbelieved, and even deplored, much of what the work in quantum theory came to imply and represent. “The more successes the quantum theory enjoys, the more stupid it looks,” Einstein wrote early in its development (Kumar, 2008, p. 153). In the last decade of his life, he was still fighting those perspectives. He lectured to Born that “if one abandons the assumption that what exists in different parts of space has its own, independent, real existence, then I simply cannot see what it is that physics is meant to describe” (Robinson, 2005, p. 92).

Einstein “refused to believe in” the black hole effects of matter curving in on itself, trapping light and anything else in its gravitational arms, and “effectively [cutting] itself off from the rest of the universe” (Hawking, 1993/2006, p. 204). In so doing, despite his apparently everlasting fame, he cut himself off in some ways from both the
mainstream and the advance guard of the field he had struggled to enter and find a place within. For example, he rejected Heisenberg’s uncertainty principle, a tenet of quantum mechanics showing that “one could not measure the state of a system exactly so one could not predict exactly what it would do in the future. All one could do is predict the probabilities of different outcomes” (Hawking, 1993/2006, p. 205). Indeed, this is a lingering problem of both physics and philosophy, “the problem of determinism, related on the one hand to the problem of time, and, on the other hand, to the opposition between the theory of relativity and quantum theory” (Wenzl, 1970, p. 586). Yet, the Heisenberg principle essentially defines modern quantum mechanics, so rejecting this principle cut Einstein off from an entire horizon of breakthrough work in the field.

In order to get around his objections to a probabilistic universe, Einstein used his work on the grand unified theory to try to find the way around mainstream quantum theory as it was evolving. The unified field theory would, he believed, complete the quantum theory and bring it into line with an orderly universe. Shortly before his death, he still maintained that “such a far-reaching theoretical renunciation [of reality by quantum mechanics] is not for the present justified by our actual knowledge, and …one should not desist from pursuing to the end the path of the relativistic field theory” (Robinson, 2005, p. 94).

Though Einstein believed that “as long as we have a good reason, we should be ready to give up any scientific principle, no matter how sacred” (Magueijo, 2005, p. 78), personal dogma about the right functioning of things seems to have been excepted from this rule for both Newton and Einstein. Newton gave up sacred old principles in order to conceptualize his theories, but then he developed the illegitimate (though useful) notion
of the ether in order to overcome his objection to “the idea of a force being able to transmit itself through empty space” (Cohen, 1955/2005, p. 217) (see also Einstein, 1920/2006). Einstein then relinquished the sacred principle of the ether, along with, among other principles, Newton’s classical explanation of gravity and Euclid’s geometry (Lorentz, 1920/2004) in order to answer compelling questions of relativity (Einstein, 1920/2006b). But then, as Newton supported his own bias with a fabricated ether, Einstein threw his own lot in with an illusory unified theory in part to support his bias against “the way in which quantum physics clashes with our ingrained views of how the world operates” (Zeilinger, 2006, p. 124). Unfortunately, answers to some of his compelling questions about a unified field theory may have been blocked by his inviolable bias for universal order.

Many believe Einstein’s final rejection of the consequences of quantum mechanics failed to serve him in the end, and that his dismissal of the revolutionary theory doomed his progress in the field. However, Kaku argues that this is “a myth perpetuated by …historians and journalists who are largely ignorant of Einstein’s scientific thought…. [or are] not fluent in the mathematics” (Kaku & Thompson, 1995, p. 32). But, on the contrary, not all who dismissed Einstein’s later work and called him wrong for ultimately rejecting quantum physics were necessarily ignorant of the essentials. Weinberg (1992), who called Einstein “unusual in rejecting quantum mechanics altogether” (p. 73) and regretted the waste of Einstein’s latter unproductive years (Weinberg, 2005), won the Nobel Prize for Physics in 1979 for his contribution to the unification of the weak force and the electromagnetic force, and surely was fluent in the mathematics and in Einstein’s scientific thought.
Still, Kaku and Thompson (Kaku & Thompson, 1995) insist that “a careful scientific reading of Einstein’s work…[shows] clearly that Einstein eventually accepted the validity of quantum mechanics [but believed] that quantum mechanics was an incomplete theory… not a final theory” (p. 32), as Newton’s gravity theory was “merely incomplete” (p. 32). Indeed, Einstein’s own general theory of relativity is incomplete in that “it needs an added ingredient [quantum mechanics] in order to determine how the universe should begin and what should happen when matter collapses under its own gravity” (Hawking, 1993/2006, p. 204).

Instead of actually refusing quantum theory in the end, Einstein, according to Kaku and Thompson, thought the unified field theory he sought would eventually “account automatically for the features of quantum mechanics” (Kaku & Thompson, 1995, p. 32). In fact Einstein, in 1949, discussed his desire to account for the quantum with a universal theory that would negate probabilistic outcomes. He expressed his “expectation that the adequate formulation of the universal laws involves the use of all conceptual elements which are necessary for a complete description” and that “it is likely that the laws would [then] represent relations among all the conceptual elements of this description which, per se have nothing to do with statistics” (Einstein, 1970/1949, pp. 672-673). It seems that Einstein may not have rejected quantum theory so much as he just set it up on the same workbench where he searched for the unifying theory. He waited to embrace a fully realized picture of the quantum universe that must, when the last piece was in place, necessarily conform to the shape of an orderly cosmos.

Many contemporary quantum physicists believe that the key to a complete unified theory will lie in the successful synthesis of Einstein’s relativity and the difficult-to-
reconcile quantum mechanics (Hawking, 1993/2006; Kaku & Thompson, 1995.)

Hawking explains that one result of combining the two theories is the paradoxical finding that:

Time itself had a beginning about fifteen billion years ago and [it] may come to an end at some point in the future. Yet in another kind of time, the universe has no boundary. It is neither created nor destroyed. It just is. (p. 199)

Unfortunately, for Einstein, such a synthesis might reconcile nothing.

To the end of his life, Einstein doggedly and optimistically worked on his unified field theory, which should, he felt, bring together theories of gravity and electromagnetism in a way that would explain everything about the physical world. Many scientists, including Weinberg (2005), believe this last three decades of his work was “not only without success, but without leaving any significant impact on the work of other physicists” (p. 102). These years at Princeton’s Institute for Advanced Study were indeed marked by his opposition to the work at the forefront of theoretical physics. Regis (1987) comments on the irony:

He had been brought to the Institute for Advanced Study to prove what a forward-looking place it was, but virtually his first significant act there as a physicist was an attempt to overturn the theory that seemed to be the wave of the future. It was as if he were taking physics back to the Dark Ages, and other physicists were a bit distressed. J. Robert Oppenheimer [visited and commented that] “Einstein is completely cuckoo.” (p. 24)

Gell-Mann (2004) claims that “the way [Einstein] was going about [the unified theory] clearly doomed the work to failure” (p. 42). He found Einstein’s work so
irrelevant that when he was a post-doctoral student in physics at Princeton in Einstein’s later years, he would often pass Einstein and speak a short greeting, but found no reason or wish to engage him further.

Yet the passion of the man and quest itself has inspired following generations to carry it on. These successors have made significant contributions that seem to advance the cause of, if not finally answer, the question of a theory of everything. Kaku is one such inspired successor. He relates the early impact of Einstein’s struggle on his own young imagination: “If the man was that great, the boy reasoned, then his unfinished project must have been wonderful—the crowning achievement in his illustrious career” (Kaku & Thompson, 1995, p. ix).

Obviously there are a number of perspectives on the work of Einstein’s later years: was it a contribution for the ages, a sad waste of time and talent, or something else? Further, scientists and historians of science offer a number of viewpoints on where Einstein went wrong, if indeed he did, in his work on quantum theory and the unified field theory. This disagreement is not surprising, as the interpretations of Einstein’s work and life vary, even on the point of whether he was a scientific revolutionary, evolutionary, or reactionary (Poincaré, 1909; Tipler, 2006). Some believe he abandoned his earlier, successful principle of developing theory from a clear visualization of empirical phenomena. Instead, lacking an orienting vision of a physical situation, he seemed to get tangled up in the complexities of esoteric mathematical forms, seeking answers in those abstractions rather than in his mind-pictures of a physical situation he wanted to understand (Anderson, 2005; Kaku, 1995; Lenzen, 1970).
Quintessential Adult Learner

When Einstein broke out of obscurity, he knew he was on to something big. Despite the battering effect of having failed to be accepted into his field, or simply to find work to support himself and a new family, he still carried with him both the confidence of youth and the self-assurance that seems to accompany many self-driven individualists. In fact, he was so convinced of the eventual acceptance of his unconventional insights that, a few years after the debut of his first relativity theory, he promised his wife his eventual Nobel Prize winnings (not achieved until much later) as a settlement for their divorce (and he paid up, sending the $32,500 prize to his ex-wife once it had been awarded [Brian, 1996]). But even with these high expectations, Einstein could not imagine that his dogged pursuit of his own idiosyncratic undertakings of learning problems would propel him not just into the inner circle of his field, but to levels of fame and celebrity that he would never entirely understand or accept (Robinson, 2005).

That celebrity has now outlived the man by nearly six decades (Einstein died in April, 1955). The New York Times referred to Einstein as “the most thoughtful wonderer who appeared among us in three centuries” (Isaacson, 2007, p. 545). Time magazine named him Person of the Century. Inventor and science fiction luminary Arthur C. Clarke recognized that Einstein “is just as easily recognized in rural India or in remote Siberia as in Europe or America” (Clarke, 1972/2005, p. 235). The legacy and fame of Albert Einstein is indeed phenomenal. Schlipp (1970) called his death in 1955 “an irreplaceable loss to science, to scholarship, to humanitarianism, to the cause of peace, and to the conscience of mankind” (p. xvii).
Describing Einstein’s transformative impact on the popular imagination, Bodanis (2000), distinguishes between two archetypes. A priest, he says, “merely stands below an open hole in the sky, and lets the truth that’s normally kept hidden up there come pouring down” (p. 216). A prophet, on the other hand, “manages to journey up through that opening” and return. “We’ll try to glimpse, in the expression on [his] face, or in the potent equations [he has] plucked and brought back down, what things are like up there, in that higher realm, which so many of us believe in, but know we’ll never get to visit directly” (p. 216).

Einstein the “prophet” set the imagination of the world aflame. Even while those in the scientific community barely (if at all) understood the technical underpinnings and implications of Einstein’s theories in the early decades of relativity (Holton, 1982/2006), the public was enthralled without even trying to plumb the obscurities. Einstein and his work gradually attained a celebrity status that endures into its second century. The public seemed to perceive a qualitative shift not just in what was understood about the world but in what could be understood, and sensed as well that the foundations of human experience (time, space, motion, and perspective) were somehow more consequential and mysterious than common experience suggested. Even if not well understood, the transformation captured imaginations.

Einstein the learner also captured imaginations. Numerous young people have joined physics programs, inspired not only by Einstein’s famous results, but by his obvious delight in the search (Kaku, 2004). Whether despite or because of his heroic status, he seems to have stirred in a new generation of learners a sense of “If he can do it, maybe I can, too.” Confirming the “prophet” effect, millions more who had no desire to
follow in his footsteps were still eager to learn about Einstein and his work, and to read and hear what he had to say. As indicated by the sustained media appetite for anything and everything about Einstein, and the specific topics that appeared frequently, these masses of informal adult learners and curiosity seekers were fascinated not just by his discoveries but by the spirit he brought to his learning work, his unconventional approaches to education and learning, and his dark horse entry into the pantheon of revelators. This admiration for how he did things, how he learned by embracing curiosity and the world, continues even today. A recent post on a blog (unrelated to Einstein or science) acknowledged Einstein’s birthday with this comment: “Einstein has always been a fascinating person to me. Not just because of his scientific work, but because of his approach to it…and to the world” (Calvin, 2011, para. 2).

A true self-directed learner and autodidact, Einstein studied his problem with pleasure and determination. He was apparently fueled more by curiosity and delight—perhaps even enchantment—with his learning project, than by discipline. He seemed not to follow a structured program of self-teaching or a pre-determined algorithm of problem-solving, but an individualistic and organic path composed of logical next steps, the lure of the next interesting concept, and a great deal of making use of who and what was available as a learning resource.

This was a young man who strove to make use of traditional paths of learning, but who experienced at turns great frustration (hungry for education but repulsed by the learning environments and pedagogies of schools [Einstein, 1950, 1954a,b; Winteler-Einstein, 1924/1987]), outright defeat (studying to try to test ahead of his level in order to attend a more suitable school, but failing [Einstein, 1895/1987, doc. 6; Stachel et al.,
1987]), and perhaps worst feeling the ignominy of the opposition to his every effort to enter the fold of his field (struggling for years for opportunities both to work and to further his own learning while teaching or working in a laboratory [Einstein, 1898/1987, doc. 38; Einstein, 1900/1987, doc. 72]). He was an adequate-to-high achieving student but not considered exceptional, and angered teachers by showing more interest in the path of his own curiosity than in their programmed instruction. He did not try to be liked, to fit in, or to flatter, but he tried extraordinarily hard, in his own unacceptable way, to learn (Winteler-Einstein, 1924/1987).

According to academic, professional, and popular expectations, he had no business showing the world that this is how breakthrough learning is done. But this he did. He was a rogue learner, and an unapologetically excited one (Jammer, 2005). Yet his learning was extraordinarily voluntary and self-directed. He was active in career-related independent studies both while being formally schooled and as a working family man. He was both goal-oriented and learning-oriented in his motivations (Houle, 1963), and he dealt with Cross’s (1992) situational barriers (family and work-related stressors), institutional barriers (obstacles to employment which would provide access to resources for learning and experimentation), and even dispositional barriers (being intimidated by advanced materials while doing self-study, chafing against many forms of organized learning, and losing confidence and momentum during low and discouraging periods) (Stachel et al., 1987). He developed and luxuriated in a private learning group—the Olympia Academy—reminiscent of Benjamin Franklin’s Junto (Brian, 1996; Franklin, 1793/1994). Then, in later life, Einstein committed a good portion of his writings and talks to emancipatory issues and social justice (Isaacson, 2007, Jammer, 2005), becoming
an adult educator who would be welcomed into the company of contemporary adult educators (Hansman & Mott, 2010). Einstein’s lifelong learning example reads as a quintessential, if also exceptional, case of adult learning.

It is understandable that as an explorer, learner, and scientist he captured popular hearts and imaginations. He seemed simultaneously human and heroic, speaking to the humble and the fantastic in Everyman. And from that place he sparked other learners (whether to take up a career in the sciences, to work personally to understand Einstein’s contributions, or to challenge themselves in other ways by his example) to try their hand at something that seemed not just tough and rewarding but, as reflected in Einstein’s impish face and passionate words, also scintillating, daring, and wonderful.

Einstein’s work obviously transformed his profession as well. For one thing, he upset a common aphorism of physics: “[The adage was,] ‘one experimentalist can keep a dozen theorists busy.’ Einstein turned that inside out. His theories have kept thousands of experimentalists occupied” (Gibilisco, 2002, p. 530). Einstein certainly stayed well occupied, not just plumbing the universe in thought experiments and solitary mathematical gymnastics, but also publishing over 450 papers and a few books. About two-thirds of these writings were scientific, and most of the remainder was devoted to matters of peace, governance, and international cooperation (Shields, 1951). Not content merely to enjoy his central position in his field, once he finally gained entry, he communicated from that platform to the world and its leaders about his concerns for the preservation of secure societies, his love of peace and freedom, and his beliefs about approaches to education, science, and government that would advance the conditions of mankind.
De Broglie (1970), a quantum physicist and contemporary of Einstein’s, looked over Einstein’s body of scientific writing and described an adult learner who dared to ask grand questions ahead of his time and ability, to learn and grow into the problems, and to reject centuries of wisdom in order to answer them:

If most of his articles were short, there was not one among them that did not contain marvelous new ideas destined to revolutionize science, or acute and profound remarks penetrating to the most obscure recesses of the problem under consideration and opening in a few words almost unlimited perspectives….His articles might be compared to blazing rockets which in the dark of the night suddenly cast a brief but powerful illumination over an immense unknown region.

In every inquiry which he undertook Einstein always was able—and this is the mark of his genius—to master all the questions which faced him and to envisage them in some novel aspect which had escaped his precursors. (p. 110)

Einstein finally received the Nobel Prize for Physics on November 9, 1922, nearly two decades after publishing his first theory of relativity. Though he broke in from the obscurity of a solitary, private learning project, this honor represented Einstein’s full acceptance in his field and its corps of thought leaders. He was first nominated for the prize, for the special theory of relativity, in 1910. Various petitioners nominated Einstein over the years, but the nominations persistently ran afoul of the Nobel committee’s bias against theoretical work as genuine discovery. The committee felt it was their charge to reward positively confirmed discoveries of application rather than theoretical abstractions (Fölsing, 1997). Some historians further attribute the committee’s reluctance to acknowledge Einstein to “a combination of anti-Semitic venom from Lenard [a German
scientist who lobbied against awarding the prize to Einstein] and bewilderment on the part of the Nobel Prize judges” (Brian, 1996, p. 144). One of the committee members admitted that, hoping to give Einstein the award, he “spent all his time studying Einstein’s theory of relativity. He couldn’t understand it. Didn’t dare to give the prize and run the risk of learning later that the theory of relativity is invalid” (Brian, p. 144).

Einstein’s first submitted dissertation was rejected, possibly because he included his own new and controversial method of statistical mechanics (Renn, 2000). His next submission was successful, a paper on the size of atoms, called *A New Determination of Molecular Dimensions*. Einstein thought this paper “would be less likely to startle the examiners; they accepted it only after he added one sentence to meet the length threshold” (Holt, 2005/2006, p. 251). Einstein also published the *Molecular Dimensions* paper in a physics journal.

At last, a successful nomination for the 1922 Novel Prize was assembled and approved based on his work on the photoelectric effect, also published in 1905. The paper Einstein published on this photoelectric effect, coincidentally the only one of his papers he ever described as a revolutionary finding, perhaps seemed more practical than his theories of relativity, and it had had been confirmed by several experiments (Fölsing, 1997). Ironically, the Nobel committee continued to reject the unorthodoxy of relativity even in 1922. Holt (2006) reports:

The Swedish Academy forbade him to make any mention of relativity in his acceptance speech. As it happened, Einstein was unable to attend the ceremony in Stockholm. He gave his Nobel lecture in Gothenburg, with King Gustav seated in
the front row. The King wanted to learn about relativity, and Einstein obliged him. (p. 251)

The theory of relativity has broadly impacted human consciousness, particularly in philosophy. However, misconceptions about what the theory means and its intended limits of application have created abundant misapplication, from the crediting of relativistic perspectives in art and literature to Einstein’s theories, to a justification for moral relativism (Holton, 2006). Reichenbach (1970) takes many to task when he says:

Philosophers who regard it as an ultimate wisdom that everything is relative are mistaken when they believe that Einstein’s theory supplies evidence for such a sweeping generalization; and their error is even deeper when they transfer ideas such as relativity to the field of ethics, when they claim that Einstein’s theory implies a relativism of men’s duties and rights. The theory of relativity is restricted to the cognitive field. (p. 289)

Though Dingle (1970) recalls that “Einstein has always insisted that the theory has no metaphysical implications” (p. 550), Einstein defended metaphysical matters from those who rejected them outright (Einstein 1970/1949), and the mind-expanding, or mind-bending, inspirations of Einstein’s theories continue to arouse theory, speculation, and transformative insights about the nature of reality, consciousness, and spirituality, extending sometimes to what is known as quantum mysticism (Moring, 2004; Zukav, 1979). The logician Gödel, one of Einstein’s closest companions at Princeton in the latter part of his career, noted that relativity provided much fodder for the “philosophical minded” in that it makes of time, which “seems to form the basis of the world’s and our

Einstein’s transformative contributions extend beyond science and philosophy. Hinshaw commended his versatility: “As intellectual worker, in his role as citizen he has seriously faced so many of the vital social questions of his day” (1970, p. 661). Einstein had strong opinions about citizenship and militarism from youth (Clark, 1971; Stachel et al., 1987), and worked with increasing dedication in his later years to sponsor such causes as international cooperation and even pacifism, except during World War II when he was quieter and more circumspect about such matters, as when he said “Organized power can be opposed only by organized power. Much as I regret this, there is no other way” (Pais, 1982/2005, p. 454). Though not a religious Jew, he was an early enthusiast of Zionism, so much so that the state of Israel asked Einstein twice to serve as its president. He was working on a statement for Israel’s celebration of the anniversary of its independence just a couple of hours before the final aortic aneurysm crisis that would take his life (Clark, 1971; Goldsmith & Bartusiak, 2006; Pais, 1982/2005; Phillips & Priwer, 2005; Stern, 1999).

Einstein’s theory of relativity famously led to the development of atomic weapons, a transformative effect he naturally regretted. Concerned Hungarian physicists, émigrés like Einstein from Nazi-afflicted Europe, brought the potential of atomic weapons to his attention. Convinced of the potential application and concerned about German physicists who were likely already aware of the military promise of relativity, Einstein collaborated with the Hungarians to send a letter in 1939 to President Roosevelt. Einstein urged oversight of potential enemy development of weapons from nuclear chain
reactions set up in uranium, and suggested that Roosevelt consider having “some permanent contact maintained between the administration and the group of physicists working on chain reactions in America” (Isaacson, 2007, p. 474).

Shortly after his letter was delivered, Einstein received a thank-you note from Roosevelt: “I have convened a board to thoroughly investigate the possibilities of your suggestion regarding the element of uranium” (Isaacson, 2007, p. 476). Later, in the spring of 1945, Einstein was again prompted by his Hungarian colleagues to send a letter to the president, this time expressing “anxiety about how the bomb might be used [since] it was clear that Germany, now weeks away from defeat, was not making a bomb” (Isaacson, p. 484). Roosevelt died before reading the letter, and Truman’s administration was not swayed by the request (Isaacson).

With dramatic encouragement by the media, a popular perspective developed associating Einstein directly with the production of atomic weapons. It was “a perception that plagued him” though “his involvement was marginal” (Isaacson, 2007, p. 485). Einstein had detested the militaristic culture of the Germany of his boyhood and chafed intensely under the rigid authoritarianism of its school system. He had given up German citizenship in adolescence, later in life admitting “no friendship for any real German” (Clark, 1971, p. 32). He discussed his continuing angst about nuclear arms a few months before his death. Einstein told Linus Pauling that he hoped to be forgiven his association with atomic weapons. His limited connection to the matter, he said, was solely due to the likelihood that the Germans were working toward a nuclear weapon and might “succeed…and become the master race” (Isaacson, p. 486), a nightmare of great proportions for the Jewish intellectual and lover of liberty and peace.
Einstein used his celebrity to give support to anti-war campaigns, and he advocated a world government as a deterrent to war. These sympathies were suspect in post-war America, and while he was never a communist, Einstein’s various European associations and pacifist leanings led the FBI to create a large dossier documenting evidence that he could be either a communist or a spy (Isaacson, 2007; Pais 1982/2005; Rothlat, 2005), and to interview him at length about his connections. Whatever objective effect Einstein’s work for peace may have had, his natural courage to take the unpopular trail, and take it passionately, was a guiding light and symbol of hope for a coming transformation in American civil liberties. Educating and exhorting other adults wherever possible on issues of emancipation, justice, and the perils confronting liberty, he was an inspiration to others at a time when exercising the freedom to speak out seemed riskier than it would for coming generations. Stachel (1979/2002), a prominent Einstein scholar and editor of his archives, remarked on a respect ranging beyond Einstein’s professional repute:

I would always have revered him for his role as a symbol of steadfast resistance to the modern inquisition which threatened to destroy civil liberties in this country during the cold war years. At a time when so many institutions and individuals seemed to vacillate or give way before the onslaught of the witch-hunters in and out of government, Einstein stood like a beacon, seeming to say to those of my generation: stand fast—there is hope! (p. 85)
CHAPTER VIII

METHODS AND RESEARCH IMPLICATIONS

The important thing is not to stop questioning; curiosity has its own reason for existing.

One cannot help but be in awe when contemplating the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries merely to comprehend a little of the mystery every day. The important thing is not to stop questioning; never lose a holy curiosity. – Einstein

Methodology Synopsis

This study of self-directed breakthrough learning used a biographical case study design employing grounded theory analysis. Grounded theory methods are designed to build substantive theory regarding some aspect of practice, grounding the focused theory in the real world (Merriam & Simpson, 2000). Qualitative research develops theory inductively. Rather than testing hypotheses, the researcher uses perspectives or ideas for guidance through the subject matter (Allen-Meares, 1995; Carr, 1994). Instead of aiming for detachment and objectivity, the researcher articulates and accounts for her subjectivity as well as possible, and acts as the primary tool of investigation in the research, developing a close relationship with the data or the human subjects in order to understand the experience or phenomenon under study (Gilbert, 2002; Heshusius, 1992).

Constructivism is the epistemology guiding this research. Thus, as theoretical concepts are built upon, or grounded by, the data from which they were born (Glaser & Strauss, 1967), these concepts, in turn, are understood and interpreted by the researcher during the analysis process. From a constructivist viewpoint, the participants (or data describing their experiences) and the researcher jointly create a theoretical framework
from which to understand the situations, relationships, and processes under study (Charmaz, 2006; Clarke, 2005, 2009; Morgan & Drury, 2003; see also Newman & MacDonald, 1993).

Merriam (1989) describes the qualitative researcher’s focus as more on process than on product or result, since the process is the engine that develops the emerging model or theory. The data analysis steps followed in a grounded theory study are: coding (categorizing content), decoding (making inferences about content), and encoding (drawing conclusions about the meaning of content) (Cavaliere, 1988; Denzin and Lincoln, 2000; D’Onofrio, 2001; Glaser, 1978, 2001, 2002a). However, these steps are not fully linear or orderly, as analysis is taking place at the point of making decisions about coding, and ideas about the meaning of content are being captured from the earliest points of data gathering. The recursive nature of the process is enlightened by Krippendorff’s (2004) depiction of qualitative researchers’ justification in “going back and revising earlier interpretations in light of later readings; they settle for nothing less than interpretations that do justice to whole body of texts” (p. 88). Even the research question is likely to evolve, or should evolve, in Glaser’s estimation, as data, concepts, and relationships unfold (Babchuk, 1997). This was the case in this study, as transformative processes became more important, and the overall model of Einstein’s learning became multi-dimensional, as the analysis progressed.

Charmaz (2006) describes seven “defining components of grounded theory practice” (p. 5): (a) simultaneous data collection and analysis; (b) coding from the data rather than from deduced hypotheses or a priori theory; (c) using the constant comparative method of analyzing features of cases, data instances, codes, categories, and
emerging hypotheses comparatively throughout the investigation and through the report writing (see also Corbin & Strauss, 1990; Dye, Schatz, Rosenberg, & Coleman, 2000; Ellis, 1993; Glaser & Strauss, 1967; Merriam, 1998; Strauss, 1987); (d) theory development progressing thorough every stage of the research (grounded in the views of the participants or subjects [Creswell, 2003]) ; (e) writing memos to understand and elaborate codes, categories, relationships between them, and other aspects of emergent theory; (f) theoretical sampling which proceeds along the lines of answering questions as they appear in the research, and confirming findings which may be emerging, rather than using traditional population sampling approaches, and (g) delaying the literature review until after the grounded analysis reveals theoretical precepts (see also Couturier & Dumas-Laverdiere, 2006; Di Gregorio, 2000; Heath, 2006; Massey, 1996a, 1996b; Spickard, n.d., on this enduring controversy).

Case study research is another methodological underpinning to this dissertation. Case studies provide intensive, holistic descriptions and analysis of a single entity or a bounded system, and are often combined with other methodologies, as in this research (Merriam & Simpson, 2000). Jaccard & Jacoby (2010; see also Tellis, 1997a, 1997b) emphasize that case studies have resulted in important social science theory, and are also a strategy for generating ideas within a newer problem area of research. Historical research methods also provide some perspective on this research. The activities under study occurred around 100 years ago, and Einstein has been deceased for nearly 60 years, thus limiting the research primarily to historical documents. This potentially creates a special burden for the researcher to authenticate document credibility (Matejski (1986), and limits the avenues for testing conclusions with the subject or his contemporaries to
the strategy of checking back into the data to see whether emerging theory is, indeed, grounded in the accounts from that period.

Because of the historical nature of the research, data collection for this study was limited to documentary data (Duffy, Ferguson, & Watson, 2003; Matejski, 1986). The primary document dataset is the multi-volume set of the Einstein’s collected papers, published by Princeton University. The most recent volume, number 12, published in 2009, takes the series through 1921. (The twelve published volumes comprise 25 books, including translations, photographic representations of original documents—usually in German—editorial material, and indices.) Other primary data included books and essays authored by Einstein in the years not yet covered by the Collected Papers project, and primary documents by friends, family and colleagues of Einstein.

Data analysis for this research followed the key steps and stages of grounded theory work, using a software program developed to support the capture and analysis of qualitative data (ATLAS.ti). In addition to the specialized software for qualitative data, graphical and spreadsheet software were used in the analysis stages. The spreadsheet software was used not for quantitative analysis purposes but as a way to pull key data elements out of the qualitative database software and into a longitudinal view that allowed for comparing, contrasting, and extended theory building with a better view of the relative time scales of events and conditions. Two graphical software packages were used not just to create illustrations of the theoretical models at the conclusion of the project, but as an aid in mind-mapping and otherwise visualizing patterns and relationships among the data while developing theory.

The internal validity of the findings of this research was supported by
triangulation. The use of multiple primary and secondary data sources, and the consideration of Einstein’s multiple learning projects, provides the triangulation opportunity. “Adequate engagement in data collection,” described by Merriam (2009, p. 219; see also Becker, 1993; Bradley, 1993) as another source of internal validity, is another strength of this research given the deep and broad scope of data and literature under analysis, and the range of years of involvement with the data (Chenail, 1997, 2000). The recording of data and analysis within Atlas.ti provided an audit trail for the research project so that a reader of the database could examine the lines and layers of analysis that occurred across the project (Chiovitti, 2003; Morgan & Drury, 2003).

Generalizability, in the statistical sense, is not possible either with qualitative research or with the single case study method. Generalization from the findings is something that individual readers will choose for themselves, depending on the meaning and value each reader of the research derives from the story that unfolds from the Einstein case (Merriam, 2009), and also the extent to which the findings are useful for some comparison or theoretical extension when compared to similar studies in the field.

Testing for a Paradigm Shift

Cranton (1994) suggests a series of questions that individual educators (though this applies equally to the field of adult education as a body) should apply to a transformative learning theory. She writes:

Any theory of practice must be informed through an understanding of what others write and say, but it also must be freely chosen on the basis of experience. The educator should be particularly aware of his or her own content (What is the
theory?), process (How do I validate this?), and premise reflection (Why does this matter?). (p. 56)

Certainly these are questions that adult education practitioners and researchers must undertake when considering this expanded and integrated view of self-directed breakthrough learning. The model set presented here inserts the dimension of original learning into the common construct of learning and education, and stretches the idea of original learning to include domain-transformative breakthrough learning, suggesting that independent, autonomous, or highly self-directed learners are particularly prone or suited to engage successfully in learning projects of revolutionary impact in a field of knowledge or endeavor.

Further, the Einstein case suggests additional shifting or stretching in transformative learning theory, suggesting that domain-transformative breakthrough learning is an extension of existing transformative learning theory, that transformative learning is more common and relevant before adulthood than has been previously emphasized, and that there are multiple dimensions, approaches, levels of scale, and perspectives on completion within transformative learning, both of a personal nature and within the knowledge domain breakthrough context.

The ideas presented here include the association of breakthrough learning models from a variety of environments with the phenomena of transformative and knowledge breakthrough learning, and a focus on creativity and neurobiologically-supported theories of flow and insight as an important window on original learning work. Common conceptions of genius and exceptionality are contested as well, against a background
challenge that adult educators include exceptional learning achievement more frequently in all manner of models of practice, policy, and theory in adult education.

Finally, a model of self-directed learning behaviors in the context of breakthrough learning is presented as a component of the broader model of breakthrough learning. This model of stages, transitions, goals, behaviors, and associated plot drives may provide a more holistic view of a case of self-directed learning than similar but less dimensional models, with inherent challenges to validating a more complex model in practice or against other cases in a research context.

Implications for Adult Education

The focus of adult education research and theory development in recent years has resulted in a defining focus on issues and opportunities of social justice. Social matters have always been an important concern of adult education, for education is a social matter and adults are in a position to work for change. However, a tight spotlight on a single arena of impact, albeit a broad and significant one, can be overly constraining in any field.

What might result if the adult education field undertook a more comprehensive view of the values of diverse learning domains? If adult education succeeds beautifully in promoting social justice, a greater diversity of voices and ways of knowing, and higher levels of consciousness about power structures, relationships, and identities among humans, it will still matter whether learners who have other callings and passions succeed in their domains. It will matter if medical science has more, or less, reduced the threats of Alzheimer’s disease, cancer, autism, diabetes, and infectious disease. It will matter
whether or not engineers, scientists, and entrepreneurial inventors have developed energy sources that are sustainable as a resource base, economically and environmentally.

In a situation of fantastic progress toward social justice, we would still want to have made progress in alleviating the encroaching damage from climate change, and to have successfully navigated the communication revolutions of social media, electronic publishing, and online communities that connect and innovate yet threaten to overshadow or overthrow heritage structures related to business models, media distribution, political change, creative collaborations of all sorts, and traditional communities of family, neighbors and merchants. In the face of tremendous social progress, we would continue to hope our agriculturalists have found better ways to feed seven billion and more people from depleted soils, depleted natural fertilizer reserves, and diminishing water supplies.

We will still want our political scientists, criminologists, and public service administrators to have learned to solve problems more creatively and to have refilled their particular wells of domain knowledge and capability with new understanding, because the problems we expect them to solve will surely also be new, different, and more demanding than those of today.

And what of the seeds of new forms and perspectives that might or might not see light in the fields of art, literature, music, film, architecture, and design without support of the creative learners who are carriers of those seeds? What of new business, economic, financial, and political models that might or might not appear on the scene to help us traverse the demographic conflicts in resource allocation, opportunity, economic justice, generational career expectations, and the shifting sands of globalism and isolationism?
Should the encouragement, facilitation, and supportive theoretical basis for creative learning and new knowledge development be left to the colleges of sciences, engineering, business, and arts; to the commercial context of industrial innovation and entrepreneurial innovation, and to the winds of fate as they blow over the lone garage-based learner who is wrestling with a powerful original learning problem? Should adult education stay out of the picture, minding our knitting in our comfort zones of knowledge transmission, personal development, and social change? Truly, how dare we skirt, if only through lack of imagination, the opportunity, the responsibility, to bring to bear on the full scope of contemporary human challenges the heart, passion, and experience of adult educators for learning and progress?

Adult educators persistently want to understand their roles and positions, their places in academia and the multitude of practice contexts. What if we knock a few walls and the ceiling out of that old question and start to think bigger, from broadly new perspectives, and courageously join the larger party of big solution creation, also known as learning (and terrifyingly adult learning at that), which is underway?

Let us not be a field over-focused on a one-hit-wonder, all of our aims pinned on one goal. If we want to be change agents, and certainly that is one of the best definitions of an education professional, let us find out how learning and change works, and not just in the well-worn, though vitally important, paths of educating to prepare for economic or civic participation, or educating for greater self-awareness, growth and improved personal choices, or educating to carry the banners of history, or educating for social justice.
None of these critical aims should be left behind, but all of them fall short of informing us about how to get better at finding new solutions to burgeoning threats to our species, our world, and our culture. None of them is sufficient to help us become more nimble as problem-solvers or breakthrough artists in a speeding up world of fewer resources, more demands, and more potentially crushing crises. Adult education could have an important role at the table of critical change, and not just from the perspective of critical social theory, but side by side with scientists and technologists, psychologists and entrepreneurs, storytellers and artists and politicians, all of whom have a job to do in terms of understanding breakthrough, innovation, creativity, problem-solving, invention, discovery, original learning, or whatever we will call the work of saving the day, finding the prize and bringing it home.

We may not have the luxury of continuing to see breakthrough as something that happens rarely, unexpectedly, and is delivered by that other guy who is so much smarter and more talented than the rest of us. Continuing to delegate genius—either society in generally delegating genius to someone else up the ladder of giftedness, or adult education delegating it to another field because we are busy elsewhere and fail to see other work just as important sitting before us—is a grave mistake, and one that, given growing insight into just what drives exceptionality and originality, is also an unnecessary mistake.

Seeking social justice, opening up spaces for new voices and ways of understanding, is a most adult undertaking, and a fine aim for adult education. Adult educators are not satisfied with delegating this work to, say, sociologists and political scientists. Let us no longer be satisfied with delegating the rest of the adult work of
transformation to the various cubbyholes of academia and domains of professional researchers, inventors, and political change agents. The work of participating in and facilitating these breakthroughs, and coming to understand them better, is no less our purview than anyone else’s.

We have not been shy to take on social change in addition to transmission of traditional knowledge bases. In fact much of our history as a profession is based upon this vital work. Let us not then be blind to the further needs of our learners, and the further opportunities for us to practice our art, craft and science on behalf of values and imperatives we all share.

In the broad field of education, we educators have sometimes been known as part of the problem, whatever the problem at hand is. Many, like Einstein, believe that if not for the blunting or outright traumatic effects of formal, transmissive education, we would not choke the creativity and ingenuity out of children, nor out of adults. We have assumed that the way to shift ourselves out of the problem seat and into the solution seat is to change our perspectives on the roles, structures and expectations in the classroom. In childhood education this becomes student-centered teaching. In adult education it often looks like the principles of andragogy. These approaches are based on admirable philosophy and ideology, and may in fact be superior to traditional orientations. But we are still working inside the level of the original problem. As Einstein is supposed to have said (though there is no evidence he actually did say it, despite plenty of evidence that he embraced the principle), we have to get to a different level from the original problem in order to find the solution. We have to look at new ways of seeing the meanings within the problem.
One angle of perspective shift toward this problem is to see learning as not just transmissive, or acquisitional, but as creative and contributive and original. How can we help to make that happen? Let us start by examining a poignant critique from an adult educator who had too short a run among us, dying as she did shortly after her address was delivered to a body of adult educators. Chapman (2011) sounded a passionate call for courageous new levels of initiative and intellectual challenge in adult education:

[Adult education research] explains its field, rigorously and well, and then fails to apply it theoretically…or maybe I am just greedy for explanations beyond the self-evident….It’s the rest of the academy that is deciding whether we need to be considered a part of it or whether…it’s probably best if we don’t even try to survive because…what theory do we have or use anyway? ….We stand or fall by the weight others attribute to our scholarship….[but] what has adult education sent back in terms of theory? Not much. Our heroines and heroes tend to come from somewhere else too…we’ve maybe adapted and reshaped psychological and social concepts….[but] we just play it safe and weigh in to current educational debates…..but we’ve always been so half-hearted about theory that we’re just really tokenist” (p. 397-398)

If Chapman (2011) was correct in criticizing adult education—an undertaking and community she clearly had a heart for—as underperforming as a field in creating meaningful new learning in our own field, are we then equipped to help those we serve to do so in their fields, whatever those fields are that they find themselves facing large and luscious learning problems? If we are not equipped to support and even catalyze original
and breakthrough knowledge creation, we can certainly become equipped. If anyone knows how to get educated, that should be us.

When Chapman (who was a social-justice oriented adult educator) said that we stand or fall on the weight of our scholarship, she could also have extended that warning to the practical dimension. She could have said also that we stand or fall on the weight of the difference we make. While there may be no greater value than making a difference in social arenas, the total potential weight of difference made in the world is necessarily even greater when we embrace as learning professionals the challenge of supporting original and breakthrough learning in the knowledge and capability domains. It is a different hat for us to wear. But why not try it on?

Adult educators can take up the work of research, reflection, practice, and experimentation in the arena of breakthrough. We can contribute some breakthrough thinking in our own field in terms of educational contexts, methodologies, and pedagogies. But we can go much further. We can contribute a greater understanding of how breakthrough works from a learning perspective. We can find out how it may vary among fields, cultures, types and complexities of learning projects, varieties of environments and configurations of learners, scales of self-directedness and autonomy, levels of meaning and awareness of meaning perspective. We can carefully examine qualities of attention, and dimensions of problem-solving and insight-invoking approaches.

We can find out what difference it makes to collaborate or not in a major original learning project, to be driven by a societal goal as much as a personal one, to make a series of incremental contributions or a big, explosive one. We can add to theory in
creativity, innovation, and discovery as well as the psychologists, neurobiologists, entrepreneurs and artists among us. We can work across the aisles, as it were, to collaborate, to travel, as Chapman says, across domains to share, test, challenge, and transform theory and practice in these areas. Or, as Chapman (2011) laments:

[Perhaps] we should just churn out more of the same—more studies about motivation, participation, learning styles, orientations, and so on. Maybe more about who isn’t served by adult education but not too much on that…not too critical, just enough to show we can hit the diversity index. ….If we want to exist, we need to not just take theory but produce it. Wouldn’t it be better to encourage our students and our colleagues to be good at theory and practice, to try new things, to think differently, and, against the ways we’ve always thought, to see where it takes us? But we should still not stay home, surrounded by our old, well-worn theories. We need to get out more, invite more novel theories home for dinner, bring them into our classes, and, yes, challenge ourselves and our students out of the comfort of the known and easily understood. If we want there to be an adult education field that is seen and understood and accepted in the academy, one that works to make things intelligible and better, we need some theory to do it.

(pp 398-399)

Suggestions for Research and Theory Development

Opportunities abound for research and creative, imaginative, critical thinking in the context of a shift in theoretical territory. A half dozen suggestion categories follow in an attempt to propose ways to focus such attention to follow on the case and model set presented here. These are suggested in no particular order of importance.
First, we need more case and field research to validate, extend, and challenge the present model, and that of Cavaliere (1988, 1992), regarding the self-directed breakthrough learning work of the Wright brothers. We need to look at both historic and contemporary cases, and at situations of current learning projects with strong potential to contribute breakthrough new knowledge or capability. The lens must be broadened in many ways, to consider cases of breakthrough and exceptionally creative learning by women, by learners from other cultures, and by learners in all manner of knowledge and capability domains. The different situations of learning presented by the cases of the Wright brothers and Einstein certainly need elaboration, as more research needs to be done on the differences in the learning projects of individuals, partnerships and teams, and of tangible, pragmatic invention and abstract knowledge discovery.

What, for example, are the common learning processes and contexts of the three attention-outcome pathways in these learning projects (seeking extant answers, problem-solving to new knowledge, and taking the spontaneous pathway to exceptionally creative insight)? In a given learning project, or learning project type, how frequently does each pathway play a part, and to what effect? How do learners choose their projects, or how do their projects choose them? How often are breakthrough learning projects an exploration that extends from childhood into adulthood? What are the childhood roots, if any, of projects conceived and completed fully in adulthood? How long does a breakthrough learning project take, from earliest conception through fruition, and what are the factors that influence its lifecycle? What effect do the activities and environments a learner engages in outside the learning project have on the learning project and the learner’s experience?
Second, we need to know more about the relationships between self-directed learning and breakthrough, or broadly conceived transformative, learning. Just how critical is self-direction or autonomy in such learning? How possible is breakthrough learning, or original learning of any scale, in situations of low self-direction or minimal autonomy? Which dimensions of self-directed learning and learner self-direction are most impactful to breakthrough learning? Are any of those dimensions particularly resilient, fragile, fundamental, or otherwise special points of concern to the breakthrough learning project?

Third, let us develop a better understanding of the holistic view of the learner and learning project, as has been attempted in this dissertation but which carries great potential for different, deeper, and broader perspectives on the matter. If self-direction or autonomy is crucial to breakthrough learning, then the learner is necessarily a particularly vital important component of the learning project. In fact, calling the learner a component of the project invites a duality that opposes holism, so let it be understood that there are many more layers, dimensions, and points from which we can and should understand the learner within the learning project.

What are the factors that lead individuals to start, and to complete, or not, such learning projects—what are the barriers and catalysts? How frequently do learners entertain, on some level, provocative learning questions with original learning potential, whether or not they carry them out? What learning behaviors, strategies, and cognitive skills are frequently important to these strategies, and how are these best developed within the learner—inside or outside the learning project, independently or with
facilitation or intervention? Does the order of acquiring these learning tools or the degree of mastery have an important effect on the learning project?

What is the role of play, playfulness, or flow, on the learner and the learning project? What are the strategies whereby a learner navigates, more successfully or less, the shoals of the project—dramatically disorienting experiences, long and difficult slogs, negative outside influences, or learning tasks far beyond the present capacity or preparation of the learner? What is the relationship of life conditions on the learning project—were Einstein’s patterns of simultaneous disorientation or productive integration in life and project coincidental?

Fourth, transformative learning as a construct has been stretched and somewhat challenged in this presentation. This paradigm shift requires a good deal of assessment in theory, practice, and field research. We can look more closely at the differences in process and experience in learning that leads to personal (traditionally understood) transformation and knowledge domain transformation. There is also much to explore in terms of multi-dimensional transformative learning. How does personal perspective impact domain transformative learning projects, and vice-versa? Is personal perspective or knowledge perspective relatively easier, in terms of process or approachability, to undertake and complete? How does the inability or refusal to engage in perspective transformation affect the shape and outcome of learning projects?

Are some learners more open to and successful in navigating one or more types of perspective transformation? What facilitations, supports, or interventions are effective or appropriate in assisting the learner with either personal or knowledge perspective transformations in a self-directed learning project oriented to original knowledge
creation? These are but a handful of the transformative-learning related questions that fall readily out of the research presented here.

Fifth, how can adult educators and adult learning professionals support original and breakthrough learning overall, and the individual learner and learning project in particular? What role have educators, facilitators, mentors, peer consultants, and other learning professionals and advocates played in these learning projects in the past? When, how, and why were those roles and influences useful, or not? Does it make a difference if this learning support was provided to individuals or groups, or if it was at the learner’s request or the facilitator’s initiative, or provided at different stages in the project, or for different types of projects, in different learning environments, for different learner personalities or learning project needs? What role has formal education played within the larger context of a self-directed or autonomous learning project?

What has been the role and impact of formal or non-formal workplace learning, and the workplace environment, on breakthrough learners and learning projects, both when the work or workplace is relevant to the project and when it is not. What roles do breakthrough learners want learning facilitators to play, when, and how? How much awareness, and self-awareness, do breakthrough learners have about these matters? How do these learners tend to seek, successfully and not, outside assistance? How do they navigate unwelcome assistance or intervention, and what is the impact?

Finally, there is a large area to explore in terms of the opportunity for the larger field of adult education to make strong contributions in support of theory and practice in original learning and breakthrough learning. What can we learn from the history of adult education to inform a stronger role in understanding and supporting breakthrough
learning? How do other professional fields (psychology, neurobiology, philosophy of science, entrepreneurial studies, fine arts, etc.) support the field of breakthrough learning, as separate from supporting or creating new knowledge in their own domain, and what can we learn from these models? What research and practice is happening in areas concerned with the experience and process of breakthrough learning (e.g. in creativity research, innovation “factories”, invention projects, or research practice development) is ongoing, and what contribution would be possible for adult education and adult educators in these initiatives? What new knowledge and capabilities are being introduced now in various fields, from education theory to the psychology of creativity to neuroscience to fields as far ranging as intellectual property law, which adult educators can and should integrate into our own practice and theory, and into the preparation of future adult educators?

These research suggestions, as with the findings and interpretations of the Einstein learning case itself, are offered to the reader with the hopes that some readers will find a spark of inspiration, encouragement, or leveragable knowledge that will promote the self-directed learning project of a learner who is carrying a rich and burning question or a provocative idea for a new capability or expression. Those questions, the ones that are big and rich and burning with implacable curiosity—even though conceived, perhaps, from a tiny spark in the midst of fog—are the seeds of magic and miracle, of individual purpose and potentially global contribution. They are an important part of what makes us, as a whole, human. And when we are honored by the awareness of such a quest growing inside another learner or ourselves, and have the opportunity to experience or support its growth, we experience a powerful dimension of what makes us,
as individuals, human, and ourselves. The opportunity to experience wonder, mystery, and holy curiosity, and follow its trail into original learning, both personally and from the sidelines, is an opportunity not to be missed—for the self or for the world.
APPENDIX A

GLOSSARY

Except in the case of specific quotations, the language and interpretations in the following definitions are the researcher’s.

*Breakthrough Learning and Breakthrough Learning Project*

Breakthrough learning is an original and paradigm-transforming contribution to a knowledge field. Terms used synonymously include domain-transformative, field-transformative, knowledge-transformative, external breakthrough, technical breakthrough, and non-personal breakthrough learning.

A breakthrough learning project is one in which defining expectations, concepts, principles, models, or theories within a field are broken and replaced, or transcended, as a result of original learning which occurred within the project. Philosopher and historian Isaiah Berlin, without using the term *breakthrough learning* (referring instead to *greatness*), provided a fine operational definition. Schweber (2008) paraphrases Berlin’s conceptualization:

To deserve the attribution of “greatness,” Berlin required a thinker or artist to advance a society to an exceptional degree toward some intellectual or aesthetic goal, toward which it was already, in some sense, groping; or alternatively, to change its ways of thinking or feeling to a degree that would not, until the task had been performed, have been conceived as being within the powers of a single individual. Also, for Berlin, to be great, a thinker or artist need not have been a “genius.” (p. 2)
Electrodynamics of Moving Bodies

Einstein’s first paper on the special theory of relativity was titled *On the Electrodynamics of Moving Bodies*. The introductory premise of the paper is that electrical and magnetic forces do not seem to act on objects in relative motion (moving bodies) as they would for objects at rest relative to each other.

Electromagnetism

Describing the behavior of electrically charged particles, electromagnetism is one of the four fundamental forces defined in physics.

Established Learning

Original learning, a central component behind this research, is differentiated from established learning. Facilitation or acquisition of established learning, i.e., knowledge that already exists, is the principal mission of most educational endeavors. This integration of the appropriate knowledge bases, along with related skill sets and value systems, is generally considered the foundation for progress: developing children into adults; adults into competent producers, earners, and citizens; employees into effective contributors; individuals into growing or improving versions of themselves, and innovators and seekers of all sorts into prepared inventors and explorers.

Entropy

Described in the second law of thermodynamics (thermodynamics is the study of heat), entropy describes the increasing disorder and decreased energy, absent inputs from the outside, within any physical phenomenon.
General Theory of Relativity

The general theory of relativity, published by Einstein a decade after the special theory of relativity, is the reigning, though still incomplete, explanation of gravity. The theory unifies the concepts of space and time into a single geometric construct, and describes gravity as a result of the curving of spacetime relative to mass and radiation. The essential relativity principle behind this theory states that every observer, whether under the spell of gravity or, instead, under acceleration, should experience physical laws in the same way. The implications of this principle, as Einstein developed it, changed many precepts of classical physics and made fundamentally transformative contributions to scientific thought, including shifting the perception of time relative to motion and predicting the existence of black holes.

Generative Learning

Some learning projects, typically instigated and carried out by the autonomous or highly self-directed learner as an independent project, explore questions that are not satisfactorily answered from the pool of extant knowledge. The learners who are operating such projects are engaged in generative learning. When brought to a successful conclusion, these project have as their output new perspectives and a level of original learning, whether creative problem solving, incremental additions to the knowledge pool, or game-changing breakthrough learning. Some such projects involve all of these outcomes. The generation of new knowledge or human capability may be considered a sixth philosophical orientation in light of the standard five-type schema: cultivation of the intellect, individual self-actualization, personal and social improvement, social transformation, and organizational effectiveness.
Non-Personal Learning Domain or Context

Non-personal breakthrough learning is significant original knowledge contribution, at the level of transforming key meanings, understanding, and capability, in a knowledge domain such as physics, communication, transportation, medicine, or art. See also Personal Learning Domain.

Original Learning

Original learning is contribution to a knowledge domain, as opposed to acquisition of extant knowledge. This creative form of learning involves the discovery or creation of substantial new knowledge. Original learning may occur in many contexts and along a continuum of learning scale or significance. The determination of small bits of new understanding or previously unknown data, through formal research or informal inquiry, constitutes original learning on one end of the continuum, while radical breakthroughs like the long-anticipated creation of sentient, sovereign artificial intelligence or discovery of native life forms on other planets might represent the opposite end of the scale. This research is concerned with original learning significant enough to represent a breakthrough is important enough to cause a paradigm shift within the context of the original learning. Darwin’s (1998/1853) theory of natural selection is an example of original learning leading to major breakthroughs, in this case creating a revolution in science and a transformation in the human conversation around the origins and nature of humanity. Freud’s psychological theories and Marx’s political and economic thought are examples in non-physical science domains.
Paradigm Transformation

In the context of scientific revolution, paradigm shift or revolution is the fundamental change in the way a field or field segment makes sense of its problems of study and on what it bases the search for solutions. In a broader sense, paradigm transformation is a high-level, broadly reaching change in meaning, core understanding, or capacity for action. The development of powered flight was a paradigm transformation in transportation. The personal computer was paradigm transformation in workplace and personal productivity, communication technologies, and, lately, social structures. A paradigm solution in the personal or interpersonal context is a significant personal or socio-cultural change encompassing or eclipsing standard perspective transformations. Such a change has a highly important and reaching impact on an individual’s attitudes, behaviors, and ways of being.

Personal Learning Domain or Context

The personal learning domain is the traditional focus of transformative learning. Personal learning is not just individual learning; it also encompasses socio-cultural transformative learning. Personal learning addresses meaning and change in the being and relating domains. In the case of Einstein, an example of transformative learning in the personal domain is the cycles of his perspective transformation from a crisis in confidence in standard adult models of meaningful living to his embrace of religion, which ended in disillusionment, and was followed by an energetic and lifelong embrace of science as a significant source of meaning, along with a remaining appreciation for a creative God of the universe. An example in both the personal and the socio-cultural context is his shift from an apolitical life to passionate support first of pacifistic views,
and then of a hope for one world government which would facilitate peace, and also of
the development of an Israeli state.

Non-personal learning addresses meaning and change in the knowledge and
capability of humans in the doing and knowing domains. Non-personal breakthrough
learning is also referred to here as knowledge-transformative learning, domain-
transformative learning, or as a breakthrough learning project.

Quantum Mechanics

Quantum mechanics is the branch of physics that seeks to explain the structure
and behaviors of the world inside the atom. It is well known as a world of mystery and
weirdness. The central mystery lies in trying to explain the actions of single particles
(Moring, 2004), which, observed indirectly, can be seen to have done two different
things at once, behaving *individually* as though they already grasp a larger pattern that
would be caused by a number of particles together, but which, when directly observed,
resolutely refuse to perform this baffling trick. With no observer, a particle behaves in a
wave pattern of spooky intelligence, but under observation, the particle is once again
acting predictably as a particle, behaving with no particular inscrutability. The field of
quantum physics is divided into many interpretations and explanations of this and other
bizarre mechanics of the subatomic world.

Space-time

Three years after Einstein’s publication of the special theory, another scientist,
Hermann Minkowski, developed from it a pivotal perspective on Einstein’s theory.
Minkowski described Einstein’s theory in new terms, introducing the concept of space-
time as a single, four dimensional construct. Space-time is an instrumental feature of Einstein’s general theory of relativity.

Special Theory of Relativity

Famously, the special theory of relativity predicts that two observers who are in uniform motion with respect to each other will read different times on the clock each carries with them. This disorienting prediction is derived from the relativity principle which states that the laws of physics should not change for any observer just because he is in (uniform) motion relative to another observer. Even more famously, Einstein, in a sort of footnote published after the original paper, used the special theory to describe matter and energy as equivalent, and to say that neither could be fundamentally destroyed ($E=mc^2$).

In addition to the relativity principle about equal perceptions of the laws of physics, the special theory also relies on the constancy of light speed. It states that the speed of light (in a vacuum) does not change whether or not the light source is also in motion. This was a paradoxical concept to juxtapose with the notion of equivalent application of the laws of physics to two observers in relative motion. The two concepts—constant light speed and equal physics for objects in relative motion—contradicted each other from the perspective of Galilean classical mechanics. In fact, Einstein came to the special theory of relativity as he worked to address the dissonance, or strange results, created by classical mechanics when scientists tried to apply it to some important physics experiments that addressed the properties of light as observed from a moving state.
Though it was unarguably a transformative paradigm for physics, the special theory had a limited scope of application. It applied only to non-accelerating objects, or objects in uniform motion relative to each other (situations governed by weak gravitational fields). Einstein would work through the next ten years to understand and describe relativity in broader terms with the general theory of relativity.

**Thermodynamics**

The study of heat and other forms of energy is called thermodynamics. This field seeks to understand the physical systems, processes, and macroscopic properties related to energy conversion. However, in Einstein’s day, as the field was developing, it represented “the study of the relationship between mechanical and thermal energy—the energy associated with the disordered motions of the atoms and molecules within a substance” (Sternheim & Kane, 1991, p. 268).

**Transformative learning**

Transformative learning is perspective transformation and integration. Traditionally, transformative learning has been focused on changes in meaning schemes and perspectives in the personal and socio-cultural domains. However, transformative learning may now be considered a form of breakthrough which may apply to these traditional being and relating domains or to field transformative breakthrough in a knowing or doing domain.

**Unified Field Theory**

Einstein spent his last 40 years working to attempt electromagnetism and gravity into a theory that would unite everything that could be known about physics. He did not
succeed, and today physicists continue the search for what is now known as “the theory of everything.”
APPENDIX B

STAGE-GOAL-BEHAVIOR-TRANSITION MODEL

LEARNING JOURNEY STAGES AND TRANSITIONS

Developing the passion / Acquiring preliminaries

GOALS:
Achieve competence / mastery
Find direction / purpose
Comply / compromise
Work with self-direction / freedom

EVOLVING PERSISTENT LEARNING STRATEGIES:
Observe, investigate, experiment through playful exploration
Ponder and reflect
Think visually*
Imagine
Think independently in challenging situations
Build complex mental maps of complex spaces
Build self-reliance, critical thinking, risk taking, and problem solving
Focus intently
Think in orderly fashion
Persevere
Process unconsciously / intuitively
Think conceptually more than operationally
Work ahead to develop competence and experience challenge
Choose major challenges
Experience self-directed work as play
Require time to mull things over / not respond quickly
Problem-solve creatively
Resist non-self-directed learning
Fall in love with a concept, quest, or experience, especially with wonder
Persevere with unrewarding or difficult learning to eventually fall in love
Learn through independent practice
Practice autonomy
Take wonder into deep learning
Use study and reflection as primary teachers or routes to learning
Demonstrate confidence and resolve in face of major challenges
Seek out intellectual stimulation
Connect geometrical concepts to physical structures and experience
Build strong trust in an intuitive grasp of what “is”
Develop trust in own grasp of a situation
Act strongly to escape revolting belief system or threat to autonomy
TRANSITION TRIGGER: Formalizing and sharing project concepts / transformative paradoxical thought experiment

Coming of age
GOALS:
Experience / understand
Achieve competence / mastery
Find direction / purpose
Find tools
Find proof

Evolving Persistent Learning Strategies:
Move study focus naturally from question to understanding to question
Formalize and sharing thoughts related to learning project
Plan experiments and predict outcomes
Hesitate to over-predict
Plan for unexpected results
Test mental models
Build models and theory
Identify the problem
Set goals
Organize the problem
“Meditate” or “daydream” on the problem
Tackle intellectual and emotional challenges in service of the mission
Prioritize and discern
Drive to perfection
Withdraw or correct errors
Propose an experimental program for others to carry out
Develop sound theoretical justifications for statements and proposals
Seek feedback
Seek to share understanding
Seek recognition
Work with thought experiments
Choose independent study over formal coursework even when enrolled
Correspond with experts to gain more understanding or resources
Integrate potential solutions to puzzles into new vision of the problem

TRANSITION TRIGGER: Working with underdeveloped premises and in underdeveloped living structures

Floundering (Round I / Special relativity)
GOALS:
Experience / understand
Achieve competence / mastery
Find direction / purpose
Find tools
Find proof

EVOLVING PERSISTENT LEARNING STRATEGIES:
- Achieve mastery of knowledge bases through independent study
- Apply learning achievements / theories to additional learning problems
- Search for supporting data
- Work a promising direction until certain it is incorrect
- Replace failing strategy with a new one
- Work on simultaneous synergistic projects
- Extend prior work into deeper or broader learning quests
- Take paradox or principle from other context, apply to learning problem
- Develop courage to tackle intimidating topic or literature
- Re-study a difficult source or subject until clear
- Continue to find and study the masters and revolutionaries in the field
- Notice gaps and puzzles in the work of others
- Embrace gaps and puzzles to find solutions
- Work doggedly with focus despite lack of results
- Choose learning problems for greatest potential leverage and impact
- Find strategies for immersion in the concepts of a relevant field
- Find opportunities for discourse about new concepts
- Work on other learning problems in foreground when stuck in another

TRANSITION TRIGGER: Immersion in provocative and paradoxical learning; full project review / transformative insight

Emerging and actualizing brilliantly (Round I / Special relativity)

GOALS:
- Experience / understand
- Achieve competence/ mastery
- Find direction / purpose
- Find tools
- Find proof

EVOLVING PERSISTENT LEARNING STRATEGIES:
- Prepare to give up – release the problem
- Fully review the problem for someone else
- Present revolutionary or unpopular ideas with courage and equanimity
- Work quickly and productively when all of the pieces are in place
- Communicate clearly and concisely
- Strive for simplicity, directness in thought, solution, and communication
- Develop
- Extend
- Actualize even if it is not perfect or perfectly complete
- Start with simple, obvious strategies
- Start with most basic, direct premises
- Construct metrical model, propose tests for empirical verification
TRANSITION TRIGGER: Incomplete actualization

Floundering (Round II / General relativity)
GOALS:
- Experience / understand
- Achieve competence / mastery
- Find direction / purpose
- Find tools
- Find proof

Evolving Persistent Learning Strategies:
- Prioritize learning projects a) most significant b) approachable

TRANSITION TRIGGER: Full project review / transformative paradoxical insight

Emerging brilliantly and stalling (Round II / General relativity)
GOALS:
- Experience / understand
- Achieve competence / mastery
- Find direction / purpose
- Find tools
- Find proof

Evolving Persistent Learning Strategies:
- Build conceptual and personal momentum on in other projects

TRANSITION TRIGGER: Working with underdeveloped premises

Edging forward (Round II / General relativity)
GOALS:
- Experience / understand
- Achieve competence / mastery
- Find direction / purpose
- Find tools
- Find proof

Evolving Persistent Learning Strategies:
- Compete and debate with colleagues, subtly

TRANSITION TRIGGER: Immersion in provocative and paradoxical learning

Grabbing the reigns (Round II / General relativity)
GOALS:
- Experience / understand
- Achieve competence / mastery
Find direction / purpose
Find tools
Find proof

EVOLVING PERSISTENT LEARNING STRATEGIES:
   Work on what is manageable
   Work stepwise toward a solution to a complex problem
   Set parameters when searching for solutions
   Call on colleague-friends for help filling skill gaps

TRANSITION TRIGGER: Incomplete actualization

Completing the vision (Round III / Cosmology)
GOALS:
   Experience / understand
   Achieve competence / mastery
   Find direction / purpose
   Find tools
   Find proof

EVOLVING PERSISTENT LEARNING STRATEGIES:
   Work persistently toward complete fulfillment of vision / answer
## APPENDIX C

### TRAIL OF TRANSFORMATIONS

<table>
<thead>
<tr>
<th>DATE</th>
<th>FROM:</th>
<th>TO</th>
<th>DISORIENTING EXPERIENCE</th>
<th>REFLECTION / INTERACTION / INSIGHT / INTEGRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1883</td>
<td>Un-awareness of &quot;hidden forces&quot;</td>
<td>Delighted inhabitant of new world of mystery</td>
<td>DISORIENTING EXPERIENCE: Given a compass to play with: mysterious forces</td>
<td>CRITICAL REFLECTION &amp; PERSPECTIVE TRANSFORMATION: hidden forces are elemental, meaningful, knowable</td>
</tr>
<tr>
<td>1883</td>
<td>Dependence and limitation</td>
<td>Self-reliance and freedom</td>
<td>DISORIENTING EXPERIENCE: Navigating the world on his own: it's good to explore independently and solve your own problems</td>
<td>CRITICAL REFLECTION: Considering the meaning and opportunity of this new state of affairs, interacting with parents about new independence; INTEGRATION / PERSPECTIVE TRANSFORMATION: Acting to become a competently independent explorer in the neighborhood with blessing of authority figures</td>
</tr>
<tr>
<td>1884-1894</td>
<td>Self-reliance and freedom</td>
<td>Limitation, duty, coercion // Defensive self-direction</td>
<td>DISORIENTING EXPERIENCE: Losing freedoms to authority, structure, and treatment from private tutors and school teachers: it's not ok to learn freely, creatively, independently</td>
<td>CRITICAL REFLECTION: Struggling internally to reconcile school-based learning and freedom to pursue own learning missions; INTERACTION: Carrying as much learner sovereignty as possible into formal education; INTEGRATION: Asserting learning will, becoming ever more self-directed in response despite authority figures</td>
</tr>
<tr>
<td>1884-1894</td>
<td>Dutiful music practice</td>
<td>Passionate music engagement</td>
<td>DISORIENTING EXPERIENCE: Falling in love with Mozart</td>
<td>CRITICAL REFLECTION: This feels like learning now, and like love; INTERACTION: Joyful, focused practice; INTEGRATION / PERSPECTIVE TRANSFORMATION: Instruction and practice finally become play, and he gains sovereignty as a learner; Music now puts him in a peaceful state and facilitates reflection and breakthrough</td>
</tr>
<tr>
<td>1884-1894</td>
<td>Adults know how to navigate to life</td>
<td>Most lives guided superficially by futile material striving</td>
<td>DISORIENTING EXPERIENCE: &quot;Soon discovered the cruelty of that chase&quot;: material strivings are futile, insecure &amp; painful</td>
<td>CRITICAL REFLECTION / PERSPECTIVE TRANSFORMATION: &quot;Thinking and feeling being not satisfied by such participation&quot;</td>
</tr>
<tr>
<td>Year</td>
<td>Experience</td>
<td>Critical Reflection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1884-1891</td>
<td>Search for purpose, internal security; Religion as &quot;paradise of freedom&quot; from futile existence</td>
<td>DISORIENTING EXPERIENCE: Experiencing religion as &quot;paradise&quot; of freedom from chains of personal concerns and feelings. CRITICAL REFLECTION: Sees that religion offers clarity, transcendence, purpose, wonders beyond daily cares, and love; INTERACTING: Pursuing a path that promises answers and direction INTEGRATION: Weaving God into his central life theme of purpose, passion, wonder; PERSPECTIVE SHIFT: &quot;Came to a deep religiousness&quot;</td>
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<td>1889-1894</td>
<td>Religion as guide and succor; Finding religion to be hoax foisted on the young // &quot;Orgy of free thought&quot;</td>
<td>DISORIENTING EXPERIENCE: Science seems to contradict much of what he learned from religion; &quot;Contemplation of this world beckoned as a liberation&quot;. CRITICAL REFLECTION: Religion seems like a hoax; Men of science seem to have a reliable purpose; &quot;Positively fanatic orgy of freethinking&quot;; INTERACTING: Gains a mentor who engages him as a &quot;comrade and equal&quot;; INTEGRATION / PERSPECTIVE SHIFT: Embraces a life of science as mission, meaning, security;</td>
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<tr>
<td>1895</td>
<td>Knowledge consumer Knowledge producer</td>
<td>DISORIENTING EXPERIENCE: Undertaking a scary and exciting project: to stretch his learning to a conclusion and share it &quot;publicly&quot;; Experiencing complex emotions: anxiety, courage, humility, inadequacy, confidence, enthusiasm, admiration, optimism, &amp; deep engagement. CRITICAL REFLECTION: Feeling must discover answers to his questions for himself; INTERACTING: &quot;This is hard, but I have taken it on; I beg you not to interpret the circumstance as a mark of superficiality&quot;; INTEGRATION / PERSPECTIVE SHIFT: Establishing himself publicly as independent scholar and scientist;</td>
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<td>Oct 1895- Mar 1896</td>
<td>General fascination with underpinnings of the universe Possessing a lifetime model for discovery</td>
<td>DISORIENTING EXPERIENCE: Paradox: &quot;If one pursues a beam of light with the velocity c...one should observe such a beam of light as a spatially oscillatory electromagnetic field at rest. However there seems to be no such thing!&quot; CRITICAL REFLECTION: Turning the problem over from many angles; INTERACTING: Studying all of the professional literature he could whenever he could to better understand the problem; INTEGRATION / PERSPECTIVE SHIFT: Possessing an orienting research problem for a lifetime;</td>
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<td>Fall 1896-1900</td>
<td>Accepting classical physics of the day</td>
<td>DISORIENTING EXPERIENCE: Awakening to revolutionary ideas—Maxwell and Hertz shook up the idea that mechanics was the basis of all physics, yet E held fast for a time.</td>
<td>CRITICAL REFLECTION: spending copious time reflecting and studying alone to understand new ideas; INTERACTING: provocative conversations with classmates; INTEGRATION / PERSPECTIVE SHIFT: deep admiration for electromagnetism, thermodynamics; undertaking, planning investigations in these areas</td>
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<tr>
<td>Early 1901</td>
<td>Growing confidence in Maxwell’s electrodynamics as powerful challenge to classical physics</td>
<td>DISORIENTING EXPERIENCE: “second fundamental crisis: contradiction to Maxwell’s theory... dual nature of radiation... without having a substitute for classical mechanics”</td>
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<td>Early 1901-1903</td>
<td>Struggling with the unproven ether paradigm</td>
<td>DISORIENTING EXPERIENCE: Though Lorentz wanted to support the ether from a different perspective, E took away a conviction that the ether hypothesis was wrong; E gained another foothold on working out his own research problem</td>
<td>CRITICAL REFLECTION: Lorentz used special hypothesis to explain Michelson-Morley experiment—E considered an inappropriate explanation for an &quot;intolerable dilemma&quot;; INTERACTING: Discussing with colleagues, integrating with theoretical work; INTEGRATION / PERSPECTIVE SHIFT: Lorentz provided equations that E repurposed to change the way to measure space and time</td>
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<tr>
<td>1901-1903</td>
<td>Intellectually lonely after college</td>
<td>DISORIENTING EXPERIENCE: Establishes Olympia Academy learning club (1903) with two friends, reading Hume, Mach, Poincare, and other perspective-disrupting philosophers and scientists who would become major triggers, guides, and sustainers during his learning career</td>
<td>CRITICAL REFLECTION: stirrings of freedom from absolute time and space; INTERACTING: Working on two &quot;fundamental crises&quot;: extending Maxwell’s electromagnetism to replace mechanics; explaining Planck’s blackbody radiation; INTEGRATION / PERSPECTIVE SHIFT: Definitely drops ether hypothesis and adopts relativity principle (&quot;first great liberation&quot;)</td>
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<tr>
<td>1904-Mar-1095</td>
<td>Struggling to create emission theory of light to address problems in Maxwell-Lorentz theory</td>
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<td>Re-envisioning light as a quantum phenomenon</td>
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<td>DISORIENTING EXPERIENCE: Failing to develop a workable emission theory of light to replace the unacceptable Maxwell-Lorentz theory</td>
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<td>CRITICAL REFLECTION: working on the contradiction of light velocities</td>
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<td>INTERACTING: believes natural laws must be true for all references:</td>
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<td>&quot;how can speed of light relative to an observer not increase or</td>
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<td>decrease if observer moves toward or away?&quot;</td>
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<td>INTEGRATION / PERSPECTIVE SHIFT: began thinking about light in terms of quanta (by early 1904)</td>
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<td>Late May-June 1905</td>
<td>Despairing and releasing light and motion problem</td>
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<td>Full review of the problem with colleague Besso</td>
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<td>DISORIENTING EXPERIENCE: intensive work on light theory in prior slog years, trying to square Maxwell's electrodynamics, Lorentz's light theories and provocatively useful equations, and his sense of how nature's laws should operate, ended with letting go of some old assumptions and strategies, making room for bold new ideas to fill the gap</td>
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<td>CRITICAL REFLECTION / INTERACTING / INTEGRATION / PERSPECTIVE SHIFT: &quot;came to the conviction that all light should be defined by frequency and intensity alone, completely independently of whether it comes from a moving or from a stationary light source&quot;; published the paper that would eventually earn him the Nobel prize</td>
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<td>DISORIENTING EXPERIENCE: Ready to give up after years of work and a recent year of no apparent progress on the light-and-motion problem. Letting go is an uncommon experience for E, and puts him in a different place.</td>
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<td>CRITICAL REFLECTION: Have tried everything possible, and it's hopeless</td>
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<td>INTERACTING: Full review of the problem with friend and colleague, with long discussion INTEGRATION / PERSPECTIVE SHIFT: The perspective of sleep and dreaming, after having a GRAND REVIEW, delivered needed perspective shift</td>
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<td>DISORIENTING EXPERIENCE: Wakes up to a eureka moment: the relevance of simultaneity (&quot;second great liberation&quot;)</td>
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<td>CRITICAL REFLECTION: Considers that the result is in agreement with Mach's perspective; INTERACTING: Works this new paradigm into his research problem rapidly</td>
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<td>INTEGRATION / PERSPECTIVE SHIFT: Time is not absolute, conservation of linear momentum and energy become one principle; electric and magnetic fields have only a relative existence; mass and energy are equivalent</td>
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<td>Late 1907</td>
<td>Inability to find a handle on extending the relativity theory</td>
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<tr>
<td>Late 1909</td>
<td>Search for gravitational model</td>
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<tr>
<td>Late 1910</td>
<td>Search for gravitational model</td>
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**DISORIENTING EXPERIENCE:**
Initiates a comprehensive review of special relativity for an article: "within the structure of the special theory of relativity no niche for a satisfactory theory of gravitation"; "realize all natural laws except gravity could be discussed within the framework of the SRT. Wanted to find out reason for this

**CRITICAL REFLECTION:**
On reflection, realizes that he must talk about how relativity relates to gravity

**INTERACTING:**
Works with the idea unsuccessfully until he has another disorienting experience (Eureka moment) - theory of gravity; "there came to me the most fortunate thought of my life: like the electric field... grav field only has a relative existence.

**DISORIENTING EXPERIENCE:**
The Eureka vision of a man in freefall not feeling his weight; "Now appeared to me in its deep significance. I was most highly amazed by it and guessed that in it must be the key to the deeper understanding of inertia and gravitation"

**CRITICAL REFLECTION:**
The unusually extraordinary experimental law, that all bodies fall with equal acceleration in the same gravity field, immediately obtains a deep physical significance; INTERACTING: decided to extend theory of rel to the reference frame with acceleration... in doing so I could solve the problem of gravity at the same time

**INTEGRATION / PERSPECTIVE SHIFT:**
Says working on a new theory of gravity and thinks he will be able to explain the anomalous precession of Mercury.

**DISORIENTING EXPERIENCE:**
Born's ideas about rigid motions in special relativity hold obvious but disorienting potential for a model of gravitation fields suitable for extending relativity to a general frame.

**CRITICAL REFLECTION:**
Born's ideas have merit, but pose great challenges: "Child of sorrow, the rigid body... one should attempt to devise hypotheses about the behavior of rigid bodies that would permit a uniform rotation";

**INTERACTING:**
E and a colleague discussed the rigid-body problem and "puzzled that rigid body at rest can never be brought into uniform rotation";

**Herglotz** sets parameters around kinds of motion Born's rigidly rotating body could achieve, allowing E to evaluate those motions and the gravitational field, or inertial forces in the rotating body; **INTEGRATION / PERSPECTIVE SHIFT:**
decides to begin working with the model in his gravitational theory work; efforts more promising after adopting the rigidly rotating disk as model.
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Description</th>
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<tr>
<td>1911</td>
<td>Studying and embracing the geometric model // Realizing that a curved, rather than flat model would be needed for general relativity</td>
<td>DISORIENTING EXPERIENCE: After studying Minkowski for some time, he sees the problem differently—the four-dimensional mathematical representation has value.</td>
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<tr>
<td></td>
<td>DISORIENTING EXPERIENCE: After studying Minkowski for some time, he sees the problem differently—the four-dimensional mathematical representation has value.</td>
<td>CRITICAL REFLECTION / INTERACTING: Though the four-dimensional approach is important, the flat geometry approach of Minkowski is not adequate; INTEGRATION / PERSPECTIVE SHIFT: Published on rotating disk as a gravitational field; concluded that spacetime was curved. After mastering Minkowski's four-dimensional approach, asked Laue whether gravitational field is represented by six vectors.</td>
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<td>STRUGGLING TO FIND FIELD EQUATIONS FOR GRAVITATIONAL FIELD STRENGTH</td>
<td>DISORIENTING EXPERIENCE: Laue replies that the gravitational potential could &quot;in principle be determined by measurement of the speed of light&quot;. Laue's comment was likely the flash of enlightenment needed to point Einstein toward the path of variable speed of light.</td>
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<td>CRITICAL REFLECTION / INTERACTING: Described light deflection as result of gravity, inciting astronomers to look during solar eclipse; variable speed of light met with scorn among peers; INTEGRATION / PERSPECTIVE SHIFT: Shifted from struggle to find equation for gravitational field strength to using a variable speed of light to represent gravitational potential—critical step before turning to a geometric perspective of gravity.</td>
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<td>1912</td>
<td>Requiring spatio-temporal coordinates to have a direct physical meaning</td>
<td>Rotating disk model taught him that spatial coordinates lack direct physical meaning in this model.</td>
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<td>CRITICAL REFLECTION / INTERACTING: Published, in tentative tone, his finding of a case in which coordinates lack physical meaning. Not yet ready for integration and full perspective shift: &quot;Not so easy to free oneself from the idea that coordinates must have a direct metric significance.&quot;</td>
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<td>Trying to understand and represent disk model and gravitation with Euclidean geometry</td>
<td>Realizing that Euclidean geometry is the limiting factor in the problem.</td>
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<td>DISORIENTING EXPERIENCE: Work on stationary gravitational fields brought him back to needing a deeper understanding of the rotating disk model, and needing to face disturbing ideas: a loss about how to proceed with the paradoxical implications of his findings.</td>
<td>CRITICAL REFLECTION / INTERACTING; INTEGRATION: Rotating disk model ultimately forces realization that Euclidean geometry fails to describe this model, and might have to extend admission that space-time coordinates do not correspond directly to physical points, and inertia becomes complexly geometric.</td>
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<td>Year</td>
<td>Event/Experience</td>
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<td>1912</td>
<td>Dismissing higher mathematics</td>
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<td>Embracing higher mathematics as the path forward</td>
<td>Disorienting experience: Lacking the background in higher mathematics when he needed it critically</td>
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<td>for the balance of his life work</td>
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<td>connecting his gravitation context with Gaussian geometric geometry introduced in a lecture in college</td>
<td>Critical reflection: The field he had dismissed and somewhat avoided would hold the tools for most of what he needed to do in the rest of his career</td>
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<td>A breakthrough allowing him to frame the questions and create specifications for a different kind of mathematics required before proceeding with general relativity</td>
<td>Interacting: Working with Grossmann gave him the tools to proceed, but he never felt like he had enough mastery to satisfy the needs of his work</td>
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</table>
|      | DISORIENTING EXPERIENCE: He made the connection between Gauss's geometric theory of two-dimensional surfaces and the four-dimensional flat geometry of Minkowski's representation of the special theory of relativity | Integration / Perspective shift: "one thing is certain, that in all my life I have never struggled as hard and that I have been infused with great respect for mathematics, the subtler parts of which, in my simple-headedness, I had considered pure luxury up to now"; values these tools, searches for mathematical simplicity as for conceptual
1915

Requiring a mathematical condition called general covariance to be present in a valid set of field equations for general relativity and gravitation

Rejecting the principle of general covariance after failing to figure out how to make it work // Welcoming back the general covariance principle after a full review of the problem reveals that it should never have been scrapped

DISORIENTING EXPERIENCE: Two years of failure disoriented him to the point of reviewing the whole problem from scratch

CRITICAL REFLECTION; INTERACTING: Reviewing whole problem from scratch; retrieved generally covariant geometry, and found the error in his logic; making small changes in equations, created Einstein tensor; "my wildest dreams have been fulfilled: general covariance";

INTEGRATION: "with the new field equations, the paradox disappeared. To be replaced by a beautiful new result"; Completed the General Theory in which gravity is a result of matter distorting fabric of space-time and altering inertial motion of other bodies in its gravitational field

1915

Understanding space-time as necessarily flat in a cross section

Liberating himself from the flat cross section perspective when data reveal that a cross section of space-time need not be flat

DISORIENTING EXPERIENCE: read a paper that provided solutions for a set of generally covariant field equations

CRITICAL REFLECTION: The solution set indicated that cross sections of a static gravitational field need not be flat;

INTERACTING; INTEGRATION; PERSPECTIVE SHIFT: whereas this false belief may have been key to his rejection of general covariance, liberation helped free him to take up the right equations again

1915

Continuing to require and deeply desire that spatio-temporal coordinates to have a direct physical meaning, despite concession for rotating disk context

Releasing the paradigm of physical coordinates paralleling four-dimensional space-time coordinates now that the right equations are in place as well as the correct paradigm for non-flat cross-sections, the grip on this favored view has to loosen

CRITICAL REFLECTION; INTERACTING; INTEGRATION; PERSPECTIVE SHIFT: "through which time and space are deprived of the last trace of objective reality"; "which makes the spatiotemporal coordinates into physically meaningless parameters"
<table>
<thead>
<tr>
<th>Year</th>
<th>Philosophical posture that theory can be constructed from experiential data</th>
<th>Philosophical realism such that theories must be free creations of the human mind</th>
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<tbody>
<tr>
<td>1915</td>
<td>DISORIENTING EXPERIENCE: The experience of developing the General Theory shakes up his perceptions and philosophies of science</td>
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<td>CRITICAL REFLECTION; INTERACTING; INTEGRATION; PERSPECTIVE SHIFT: When he was younger he was more of a positivist. The experience of the relativity project made him more of a realist; Where had once felt that theories could be well constructed by using induction from experience, he now believed that they must be &quot;free creations of the human mind&quot;</td>
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<tr>
<th>Year</th>
<th>Mach's philosophical / physical principles as integral touchstone to the project and driving Einstein's static cosmology</th>
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<tr>
<td>1916-1927</td>
<td>DISORIENTING EXPERIENCE: Need for his touchstone, Mach’s principles, eventually ran its course; “although I did not exactly understand Mach’s idea about inertia, his influence on my thought was enormous”–had been willing to change his relativity field equations again to create a cosmology to fit these principles</td>
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<td>CRITICAL REFLECTION; INTERACTING; INTEGRATION; PERSPECTIVE SHIFT: By the time he gave up the static cosmology, he had also given up grip on Mach’s principle; saw Mach irrelevant in this context, an understanding that was vital to the way he approached his next significant problem, the unified field</td>
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