# Understanding and Mastering Complexity

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We welcome comments and suggestions. Pease send them to the editors.

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## Information Age Education

Information Age Education (IAE) is a non-profit company in the state of Oregon that was established in 2007 by David Moursund. Its goal is to help improve worldwide informal and formal education at all levels. Its current list of free resources and activities includes:

- Free books published by IAE. See http://i-a-e.org/free-iae-books.html.
- Free *IAE Newsletter* published twice a month. See http://iae-pedia.org/IAE_Newsletter.
- *IAE Blog.* See http://iae-pedia.org/IAE_Blog.

- *IAE-pedia*. See http://iae-pedia.org/index.php?title=Special:PopularPages&limit=250&offset=0 for a list of pages ordered by popularity.
- Other IAE documents. See http://i-a-e.org/downloads.html.

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# Preface and Overview

> "People are very complex. And for a psychologist, you get fascinated by the complexity of human beings, and that is what I have lived with…all of my life, is the complexity of human beings." (Daniel Kahneman; Israeli-American psychologist and winner of the 2002 Nobel Memorial Prize in Economic; 1934.)

> "Technical skill is mastery of complexity, while creativity is mastery of simplicity." (Erik Christopher Zeeman; Japanese-born British mathematician; 1925-.)

We humans are very complex, and we live in a very complex world. Our informal and formal educational systems, and our everyday life experiences, help us learn to deal with the complexities of complexity.

Humans are innately lifelong learners and lifelong teachers. In our interactions with each other and our environments, we learn from each other and from the environment. We are naturally curious, and this curiosity leads us to seek answers to complex questions and problems. Through oral tradition, reading and writing, and now much more complex technology such as computers, the Web, and the Internet, we accumulate information, knowledge, and skills, and pass them on to our children.

This book is intended for use in both informal and formal educational settings. All teachers deal both with the general complexities of teaching and with the specific content complexities in the areas they teach. All adults deal with the day-to-day complexities of life in our rapidly changing world. Parents have the added complexities of raising children. (And, we all face the complexities of dealing with parents who are not raising their children in a manner that we think is appropriate.) Some personal stories of learning about and dealing with complexities are included. There also is an introduction to some of the current research literature related to complexity in teaching and learning.

## Overview

We're born with a brain 1/3 its adult size. Our brain gains close to its adult size by the time we are about six years old. However, it takes nearly two more decades before our brains gain full cognitive maturity. (It can be a major mistake to look at a "full grown" teenager and think that this teenager's brain functions like that of a responsible, fully mature adult.) Parental nurturing and social forms of education assist in the task of body and brain development and maturation during our juvenile years—from infancy through childhood through adolescence into early adulthood. Our ability to understand and master complexity is the central concern of human life.

This book explores key elements of cognitive maturation. Initial chapters explore how individuals understand and then master the complexities that they confront in their lives. Play and games predominate initially, both in nurturing and in formal education environments.

Play and games can be thought of as types of analogy, the concept that's explored in subsequent chapters. Analogy uses our understanding of one concept to gain cognitive access to another currently not understood concept. For example, we use the Santa analogy to initially help children understand gift giving. The game of Monopoly has provided many of us with our initial insights into the real estate business. We use oral and written utterances as analogies for the objects and ideas they represent. Books written long ago are often difficult to understand because the authors made use of analogies that current readers have not previously encountered.

We're a social species. We thus often collectively need to understand cultural complexities. Professional organizations, political parties, churches, schools, etc., help groups of people understand the complexities of the phenomena they address. The shared experiences people gain through participation in such organizations are an important part of their education.

Progress in research and development helps to simplify some complex problems, and also can add to complexity. For example, consider our rapidly growing understanding of the human brain. This book explores the manner in which the education profession has had to shift its perspective from one in which it didn't understand the functional organization of the human brain to one in which such understanding is becoming common. Our increasing understanding of our brain's organization and functioning helps to provide a foundation for improving our educational systems.

Or, consider Information and Communication Technology (ICT), a major change agent. Children who grow up making routine use of ICT do not view this "complexity" in the same manner as adults who find some aspects of this rapidly changing technology to be such a challenge. We are moving in the direction of thoroughly integrating the routine use of ICT into our educational systems. But as long as ICT maintains its rapid pace of change, there will remain a large gap between what children seem to learn so easily and what so many adults find to be an overwhelming complexity.

Human life is finite. The final chapter describes the beautiful symmetry that exists in the extended late life body/brain decline in which systems shut down in the reverse order in which they matured decades earlier.

## Part 1

# The Complexities that Novices Face

Part 1 begins with an overview of the nature of complexity. The following five chapters focus on how humans of all ages gradually discover intriguing examples of complexity within their environment. Although they initially are novices, they can draw on informal nurturing, formal education, and social cooperation to understand and eventually master the specific complexities they confront. This can occur whether they are children who need parental help or adults who need their children's help, of if they are children who know how to talk but need school to learn how to read. They may be part of a group who discover that they need each other, or individuals who spontaneously receive unexpected help. In each case, we can be thankful that we're a social, cooperative species.

1. An Introduction to Complexity
2. An Eight-year-old Discovers Football
3. What I Learned from Learning to Play DragonVale, a Complex Online Game
4. How a Child Learns to Read
5. Co-constructed Learning Enhances Understanding
6. Spontaneously Clarifying Complexity

## Chapter 1

*(IAE Newsletter #115. See http://i-a-e.org/newsletters/IAE-Newsletter-2013-115.html.)*

# An Introduction to Complexity

**David Moursund**
**Emeritus Professor of Education**
**University of Oregon**

> "Any sufficiently advanced technology is indistinguishable from magic." (Arthur C. Clarke; British science fiction author, inventor, and futurist; 1917–2008.)
>
> "There is always an easy solution to every human problem—neat, plausible, and wrong." (H. L. Mencken; American journalist, essayist, editor; 1880–1956.)

The intact human brain is naturally curious and creative, with the ability to effectively solve complex problems and accomplish complex tasks that initially seem beyond resolution. This book deals with complex problems, tasks, and questions. It focuses on the roles of informal and formal education, the tools that enhance our physical and cognitive capabilities, and current cognitive neuroscience research that's applicable to the study of complexity.

## Complexity and Problem Solving

You have heard the assertion, "Beauty is in the eye of the beholder." Here is a somewhat parallel statement, "Complexity is in the brain/mind/body of the problem solver." What is a complex problem for one person may be a simple exercise for another, and vice versa.

I use the term "problem solving" to include dealing with:

- Question situations: recognizing, posing, clarifying, and answering questions.
- Problem situations: recognizing, posing, clarifying, and solving problems.
- Task situations: recognizing, posing, clarifying, and accomplishing tasks.
- Decision situations: recognizing, posing, clarifying, and making good decisions.

In summary, getting better at problem solving means learning to make effective use of tools, and using higher-order critical, creative, wise, and foresightful thinking to do all of the bulleted items.

A number of the TED videos provide good examples of complexity and dealing with complex problems. See http://www.ted.com/talks/tags/complexity.

## Historical Example

Early humans were prisoners of their sensory-motor limitations. They had an increasingly capable brain, but couldn't yet get beyond its solitary limitations. One solution was to blame evil spirits. Another was the beginning of the long intellectual trek towards "science-based" solutions to problems they faced—to try to understand underlying reasons and theory, and then try to figure out solutions.

The concepts of germs and germ theory provide an interesting historical example of such complexity. Before germs were discovered, people blamed various diseases on evil spirits and tried to develop techniques to avoid or placate these evil spirits. Eventually researchers developed tools and knowledge that were a more useful explanation than that of evil spirits. Quoting from http://inventors.about.com/library/inventors/blleeuwenhoek.htm:

> [Using a microscope] Anton Van Leeuwenhoek was the first to see and describe bacteria (1674), yeast plants, the teeming life in a drop of water, and the circulation of blood corpuscles in capillaries.

Leeuwenhoek's careful research, combined with the use of a relatively new scientific instrument, helped to dispel the magic and pave the way to major changes in our understanding of medicine. Now, soap and water, handkerchiefs, hospital cleanliness, and antibiotics help address the continuing complex problem of bacterial infection. See https://en.wikipedia.org/wiki/Germ_theory_of_disease.

## Mind and Body Tools

Over the millennia, humans have become increasingly good at creating and using mind and body tools to help solve complex problems.

### Ancient Tools

Current research suggests that the first anatomically modern human developed about 200 thousand years ago. See http://en.wikipedia.org/wiki/Anatomically_modern_humans. Long before then, our earlier ancestors developed and used tools to cut and spear, to control fire, and to create clothing. See Wong (March, 2013) and http://en.wikipedia.org/wiki/Clothing#Origin_of_clothing.

### Reading, Writing, and Arithmetic

The 3 R's are examples of brain/mind tools. Agriculture was developed a little more than ten thousand years ago. This made it possible for nomadic hunters to gather in villages (farming communities). The expansion of agriculture, population density, and commerce led to the need for reading, writing, and computational arithmetic based on using reading and writing. These were developed a little more than five thousand years ago.

The early agricultural practices could be learned through a combination of imitation, informal education, and on-the-job training. However, reading, writing, and arithmetic provided a different type of complexity and educational challenge.

### Some Modern Tools

I find it quite interesting to see children using a "black box" that we call a smart phone. Fifty years ago, before the invention of the first cell phone, many people would have thought of today's cell phone as magic. Today's children have relatively little trouble learning to use a smart phone—they learn from each other and by experimentation what it can do and how to "do it." However, they usually have very little insight into what is inside the box and how it works. In many problem-solving situations, people now "call on" their smart phone rather than on the deities for help. For more discussion of this topic, see Moursund (2010).

## We Are a Social Species

We're a social species, so not everyone has to start from scratch and figure out how to solve each particular problem or concern. A few inspired problem solvers are enough, because the explanation and solution can then spread through informal and formal educational processes and technologies. Central to all of this is:

1. Using our increasingly educated higher-order, critical, creative, and foresightful thought processes.
2. Developing tools that aid our brains and physical bodies.
3. Broadly disseminating the results of innovation via demonstration, informal and formal education, and product development and marketing.

Smart phones and tablet computers provide an excellent example. Typically they combine telephone, cameras, data collection, Internet connectivity, and computers. The combination of such tools is of considerable value to users. The social value is seen in the very high usage level of these tools in messaging and social networking, and in other types of communication and sharing in our daily lives.

The worldwide installation of smart phones now exceeds the installed base of laptop and desktop computers. See http://www.forbes.com/sites/louiscolumbus/2013/01/17/2013-roundup-of-mobility-forecasts-and-market-estimates/.

## Complex Individual and Group Problems

Ownership is a key issue in problem solving. I might have a particular problem that does not interest or concern you. The ways in which I deal with my personal problems may be quite different from the ways in which you deal with your personal problems.

Many of the problems faced by an individual are different from problems faced by a family or neighborhood or community. Those problems often differ from those faced by a corporation, city, state, nation, or the earth.

For example, the U.S. federal government is challenged by many interacting and overlapping national issues, exacerbated by diverse perspectives within the congressional, executive, and judicial branches of the government. Consider just a few: debts and income, international competition, worldwide sustainability, malnutrition, disease, terrorism, education, aging, and rapid changes emerging out of science and technology. The levels of complexity are overwhelming.

Thus, in total, clearly identifying problems and tasks important to various people, groups, organizations, and entities, and making progress toward their solution, is a very challenging and complex endeavor.

It is unreasonable to expect that a person will gain a high level of expertise in solving all of the different types of problems the person encounters in life. Instead, our educational system and employment practices facilitate the development of people with a high level of expertise in one or a few areas, and we have come to make use of such expertise. For example, individually, we hire experts to deal with complex medical, investment, housing, and education problems. Of course, this approach to dealing with complex problems creates the problem of earning enough to pay for such goods and services.

The well-known phrase, "It takes a village to raise a child" identifies child rearing as a complex problem. We're a social species who have learned to live and work together in dealing with child rearing and many other problems related to the survival of our species. Think about how parenting, schools, and informal education provide the basic skills that children need to understand and solve more complex problems.

Benjamin Bloom captures the essence and promise of education:

> After 40 years of intensive research on school learning in the United States as well as abroad, my major conclusion is: What any person in the world can learn, almost all persons can learn, if provided with the appropriate prior and current conditions of learning. (Benjamin S. Bloom; American educational psychologist; 1913–1999.)

The Internet, Web, and Massively Open Online Courses (MOOCS) are all modern aids to help people gain the knowledge and skills they need to solve problems and accomplish tasks that interest them.

## Telling the Stories

Subsequent chapters will relate stories about how individuals and groups come to understand and master complexity, and how using these examples can improve school instruction. For example, Chapter 2 tells how a parental football fan helped his interested eight-year-old son understand the complexity of football. Some combination of a father and son bonding, individual parental tutoring, and intrinsic child motivation led to relatively quick and deep learning. Intrinsic motivation and individual tutoring can and do enhance learning.

The young can also teach their elders. Chapter 3 describes how an adult learned a computer game through the help and encouragement of two daughters and a granddaughter. This very moving personal experience reinforced my belief that one is never too old to learn, and that each person is a teacher. The story also gives new insights into informal ways of teaching and learning.

Chapter 4 describes how the education profession moved from a Behaviorist perspective of teaching to our modern one, which incorporates discoveries being made by cognitive neuroscientists. During the past 50 years, educators have moved from being relatively naive about the neurobiology of the brain that defined their profession to becoming quite knowledgeable. They could not have been accomplished this without the assistance of cognitive neuroscientists.

## Final Remarks

The complex problems of long-distance communication and transportation, together with a need for storage and retrieval of written materials, graphical materials, sound, and video have led to the development of the printing press, steam locomotive, telegraph, photography, telephone, audio recording and playback, radio, cars, airplanes, television, computers, and space ships. The early abacus helped us to perform arithmetic, and we now routinely use calculators and computers in this task. Many of the complexities of disease are now understood at a level that has allowed the development of medical practices and aids that are helping us to deal effectively with many of these complexities.

Many of the tools we have developed to aid our physical and mental capabilities are so complex that it takes years to master their effective and appropriate use. In addition, our efforts to deal with such complexity often lead to the development of still more complexity.

In summary:

> It isn't enough just to learn—one must learn how to learn, how to learn without classrooms, without teachers, without textbooks. Learn, in short, how to think and analyze and decide and discover and create. (Michael Bassis; American educator and author; 1946–.)

## References

The documents listed below are for this particular chapter. References from the individual chapters have been collected in the References section at the end of the book.

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## Chapter 2

*(IAE Newsletter #116. See [http://i-a-e.org/newsletters/IAE-Newsletter-2013-116.html](http://i-a-e.org/newsletters/IAE-Newsletter-2013-116.html).)*

# An Eight-year-old Discovers Football

**Lawrence Sylwester**
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> "Pedagogy is what our species does best. We are teachers, and we want to teach while sitting around the campfire rather than being continually present during our offspring's trial-and-error experiences." (Michael S. Gazzaniga; American professor of psychology; 1939–.)
>
> "Children are the message we send to the future." (Abraham Lincoln; 16th President of the United States; 1809–1865.)

For those of us who have been lifelong football fans, it's easy to forget just how complex the sport is. This past season helped me remember that very thing when my 8-year old son Zed suddenly and unexpectedly started spending Saturday and Sunday afternoons next to me watching the games on TV. He asked incessant questions about who was doing what, what had just happened, and just about every annoying question a football fan can imagine. But knowing that no stronger bond between father and son exists than sports, I patiently answered his questions and did my best to explain everything from fake punts to fourth and inches.

By mid-season he was catching on, and by the end of the season, which just so happened to coincide with a startling resurgence of our hometown Seattle Seahawks behind their matinee-idol rookie quarterback, Russell Wilson, he knew things I didn't.

In mid-January, the whole family went to a friend's house to watch the NFL playoff game between the Seattle Seahawks and Atlanta Falcons. The Seahawks fell behind in the first half, but then came roaring back during an exciting second half and took the lead with minutes to play. A win would put them into the NFC championship game against their bitter rivals, the San Francisco 49ers, one step away from the Super Bowl. But suddenly the defense bent a little too much and the Falcons kicked a field goal in the final seconds to win the game.

We were all disappointed by losing after such an excruciating up-and-down finish, and I noticed that Zed was sobbing inconsolably.

Having once been Zed's age, I knew that a heartbreaking loss by a favorite team could indeed bring tears, so I knew exactly what to say. I held him on my lap and whispered into his ear that the Falcons were now our worst favorite team ever. Between sobs he kept saying how he hated the Falcons, and I told him I agreed—I hated them too. We were united in our hatred for the Falcons.

After a while he pulled himself together and went outside to play catch with his friend Julian.

## What I Learned

Perhaps the most remarkable thing I've seen as a parent is Zed's new love affair with football. A few months earlier, he didn't care one whit about football, and knew next to nothing about the sport or those who played it. Any attempt to get any of my three children to watch a game with me typically led to whining that they wanted to watch something on the Cartoon Network or the Disney Channel.

Then things suddenly changed for Zed. But what's remarkable is the thoroughness of that change. Suddenly he "got" it. He learned a remarkable amount. He suddenly knew the NFL teams, their records, their uniforms, and their past and upcoming schedules. He knew the players, the player's numbers, and what position they played. He understood the rules, penalties, and strategies—even many of the fine differences between college and pro football. He spent hours on YouTube watching plays from previous games and even seasons!

Zed and I watched at least parts of many weekend games and the entire Seahawks' games. He always asked me who we are "voting" for. After I told him you don't "vote" for teams, you "root" for them, he thereafter phrased it correctly.

## The Experience Spread

By the time Christmas arrived, footballs and jerseys were the only things on his list. We bought him a Nintendo 3DS and a gift certificate to Game Stop, which he immediately used to buy Madden Football. His uncles in Cleveland, Pittsburgh, and Washington DC all bought him jerseys or sweatshirts from their home NFL teams. My brother bought him a nice leather football that he regularly took to bed with him.

His friend Julian was making the same transition and the two of them would play mock football games against each other. For some reason, Julian disliked the Washington Redskins so when Zed wore his new RG3 Redskins jersey one day, Julian got angry at him.

Seattle's crushing loss to the now-hated Atlanta Falcons was more difficult on Zed than it was on the rest of us. It was, after all, his first season as a football fan so he was unaccustomed to the kind of heartbreaking losses that can occur in football games. But this loss meant that the Seahawks would have seven months before the start of the next season. For an 8-year old, that's an eternity.

We had a Parent-Teacher conference during Zed's Great Transformation. I told his teacher why I was fascinated by Zed's sudden interest in and comprehensive understanding of football, and why this sort of development should also interest teachers.

As I wrote earlier, those of us who have been football fans since childhood can easily forget just how complex the game is. Consider the various positions within a variety of defensive and offensive schemes that all depend on the down and field position, the mind-boggling number of plays and formations each offense uses, and the complex rules and penalties. Immediately after the ball is snapped, all 22 players sprint in different directions for a few seconds—after which the TV commentators spend 30 seconds or so analyzing the play and rerunning it in slo-mo.

Any first time observer would immediately be lost. Reruns and slow motion are valuable learning experiences.

## Emerging Ability to Understand Complexity

I believe that Zed's sudden grasp of football is reflective of his emerging ability to understand complexity in other things. Consider how children grasped the complexities of the Harry Potter series with its made-up terminology, make-believe events, shifting characters, and developing plots and story lines. The books are full of such complexities, not unlike 22 NFL players simultaneously running in different directions when the ball is hiked. The reader has to discern what's going on and why, just as football fans have to make sense of what's going on during any given play.

Zed's falling in love with football provided him a real developmental opportunity to understand something very complex. I discovered that he knew things I didn't know (such as the record and team members of the Seahawks' opponent) or that I couldn't remember (such as the scores of previous Seahawks games). Some children start to read complex books or explore an aspect of the natural world. Zed had been interested in the mysteries of Pokémon, but mastering the greater complexities of football quickly displaced that.

The 2013 season is less than two months away, and we're already gearing up for another exciting season that won't be complete until the Seahawks win the Super Bowl.

## The Mastery of Complexity

Play and games provide young people with a non-threatening exploratory venue for the complex challenges they'll confront as adults. Play involves informal or small group explorations with a minimum focus on goals and rules. We eventually wonder how our skills compare with others, so rule-bound scored games provide a clearly defined common goal. Referees adjudicate rules because players typically push the edges of what's appropriate. Collaboration and competition become central in games—and in life.

Young people often have no conscious awareness of the underlying significance of their play and games. A three-year-old on a tricycle is beginning an exploration with wheels that will result in an adolescent driver's license. Skills needed to be a good driver are built on years of play.

The universal fear that young people have of scary stories and risky play/games relates to our need to develop and maintain cognitive systems that process the important emotion of fear. Emotional systems must develop and maintain their capability to effectively recognize and respond to dangers and opportunities. Watching a competitive NFL game next to a protective father is much safer than playing it, and (I believe) better that manipulating players on a video game.

Some of these emotions and motor skills may not be sufficiently activated in normal developmental life, so observing them physically by watching games or mentally by reading books and watching films play an important developmental role. The play/game impetus thus seems to be built into curious developing children. And if it's not emerging intrinsically, parental and community educational systems will certainly seek to activate it (Sylwester, 2007).

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## Chapter 3

*(IAE Newsletter #117. See http://i-a-e.org/newsletters/IAE-Newsletter-2013-117.html.)*

# What I Learned from Learning to Play DragonVale, a Complex Online Game

**David Moursund**
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> "When you are up to your neck in alligators, it's hard to remember the original objective was to drain the swamp." (Adage, unattributed.)
>
> "The most dangerous experiment we can conduct with our children is to keep schooling the same at a time when every other aspect of our society is dramatically changing." (Chris Dede; American computer educator and futurist; 1947-.)

Recently my older daughter introduced me to the game of DragonVale. See http://dragonvale.wikia.com/wiki/DragonVale_Wiki and http://www.backflipstudios.com/games/dragonvale/. She got me started in using this free game on my iPad. I then received additional help from my younger daughter and her six-year-old daughter. For me, this was a wonderful learning experience!

In DragonVale, a player: earns gold coins; acquires gems; buys food; breeds, hatches, and raises dragons; runs dragon races; buys buildings, habitats, and decorations; and earns experience points. A player can have "friends"—other players of the game. Friends can give each other gems without depleting their own gem collection. This gift feature, email conversations, and phone conversations help make the game into a social endeavor.

When I play the game, I can see increases in my experience level as I make complex decisions about the dragons, habitats, selection of breeding pairs, and so on. I get instant feedback on the results of my actions. If I try to do something that violates the rules, I get instant feedback that helps me to learn the rules. Playing the game well requires planning ahead and making good decisions on how to use one's acquired coins and gems. All parts of the game play contribute to both instant gratification and longer-term gratification.

The game is cleverly designed so that there are challenges to moving up in experience levels and thus being able to acquire some of the "really neat" dragons. Players who want to spend real money (not the "play money" of the game) can use a credit card to buy additional game coins, gems, or food. It is even possible to buy "time" so the dragon eggs hatch more quickly or other time-based activities go faster. That is how the company that owns the game makes money.

For many players, the need for still more instant and longer term gratification leads to their spending real money. I find this to be a quite interesting business design, and many game companies make use of it.

## My Story

There are several parts to my DragonVale story:

1. As far back as I can remember, I have been somewhat addicted to games. I particularly like games that require thinking and planning ahead. I suspect this addiction is expressed in genes that run in my family. In any case, from time to time over the years I have struggled with this addiction. In some games there is something inherently intrinsically motivating—along with both instant and longer term gratification—that is hard to control. It is like getting engrossed in reading a very good novel you "just can't put down," but even more so. Indeed, I tend to think of playing a game of solitaire on a computer as somewhat equivalent to reading a good short story. The familiarity I have with the "characters and plot" (rules) in the solitaire game make it easier to play than reading a new short story. So, one part of the story is how playing DragonVale connected me with my past and helped me to better understand myself.
2. A second part of the story is what I learned about myself as a learner. In some situations, I am a relatively slow learner. As my older daughter was showing me how to play this very complex game of DragonVale, she commented that she knew six-year-olds who were faster and more venturesome in learning the game. In learning new things, I spend a lot of time thinking and trying to understand, rather than just "doing." This learning for understanding approach has served me well for many years. Today's parents, teachers, and I are faced by a new kind of learner. They tend to be "fearless" in the type of trial-and-error learning that computer games provide. See http://i-a-e.org/iae-blog/a-new-kind-of-learner.html. Our educational system is struggling with how to make use of this new type of innate learning ability.
3. A third part of the story is about introspection and metacognition. Even quite young children can practice metacognition (thinking about their thinking) and reflect on what they are doing and learning. See http://en.wikipedia.org/wiki/Metacognition. As I learn a new game, I reflect on my own learning. What am I learning about learning and to what extent am I able to transfer learning from my previous learning experiences? I think about what I am learning that will be of use to me outside the world of gaming. For example, what am I learning about people? Will computer games deal a major blow to our educational system, family values, and long-existing cultures? What am I learning about the design of intrinsically motivating learning environments? Am I gaining new insights into the competition for the minds and time of students? What can I learn from the game design about education and improving educational systems?
4. The final part of this story is the fun I have had in helping my seven-year-old grandson learn to play DragonVale, and the time we have spent sitting together with our two iPads, playing the game and socializing. It is fun to watch a child learn!

   *(Note of modest pride: I have also enjoyed my progress in mastering the game and raising my overall game score into the upper 2% of all people who have played the game! No wonder kids like these games!)*

## Educational Implications

A well-designed computer game provides a high level of both instant and longer-term gratification. The game is mentally stimulating and challenging. It provides feedback on how well a player is doing in each "move" as well as cumulatively.

However, progress toward achieving a good education is not easily measured in terms of gaining an increased number of dragons, gold coins, food, gems, buildings, and so on.

In schools, our measures of student learning progress are neither fine-grained nor so immediate. Sure, we can use computer-assisted learning materials that provide students with instant feedback on their answers to various types of problems and questions related to the material. However, take the examples of reading and mathing. How can a student tell from minute to minute, hour to hour, and day to day how much progress he or she is making in learning to read and to do math? How can a student get up-to-date measures that reflect the "forgetting" and declines in performance that occur through lack of practice and routine use? How do students learn about progress they may be making in becoming a faster, better, more mature learner? How can a student gain relevant information about how well he or she is doing in transfer of learning and applying new knowledge and skills to solving novel problems and answering novel questions?

Schooling focuses on a very broad range of knowledge and skills. Smaller class sizes, small group discussions in a class, one-on-one tutoring, and high quality computer-assisted learning materials can all help to provide faster and more relevant feedback to students and thereby help improve their education.

## Suggestions for Parents and Teachers

The home environment provides many opportunities to help improve the education of your children. Their interest in computer games can serve as an opportunity for you to learn from them and for them to learn from you. Here are three suggestions

1. Familiarize yourself with computer-based learning materials in which children and adults play together, learn together. I suggest that you examine the free book *Play Together, Learn Together: STEM* (Moursund, 2011). Have children teach you the types of games they play, and actively participate with them in playing the games and talking about them. Gradually challenge them with increasingly complex games appropriate to their ability level.
2. Think about what you can do to provide more feedback to the children you interact with. For example, suppose you ask your child, "What did you learn in school today?" Facilitate and encourage a "deep" answer that allows you to learn, allows you to provide feedback, and allows your child to make active use of the knowledge and skills that are being taught. Pay particular attention to transfer of learning. You want your children to learn to routinely apply their school learning to situations outside of school.
3. In conversations with your children, role model the technique of routinely posing an "interesting and relevant" question, then using the Web to search for answers. Help your children gain increased skill in developing well-posed questions, searching the Web for possible answers, reading and understanding the information retrieved, deciding on the quality of the information, and applying it to answering the posed question. Again, gradually increase the complexity of the questions.

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**Chapter 4**

*(IAE Newsletter #119. See [http://i-a-e.org/newsletters/IAE-Newsletter-2013-119.html](http://i-a-e.org/newsletters/IAE-Newsletter-2013-119.html).)*

# How a Child Learns to Read

**Marilee Sprenger**
**Consultant, Teacher Educator, Author**

> "Learning to read literally rewrites the organization of the brain."
> (J.M. Fletcher)
>
> "So please, oh PLEASE, we beg, we pray,
> Go throw your TV set away,
> And in its place you can install,
> A lovely bookshelf on the wall."
> (From *Charlie and the Chocolate Factory* by Roald Dahl.)

## A Child Is Born; A Reader Is Made

My granddaughter, Maeven, could already recognize the voices of her mother and father at birth. She had been able to hear her mother by the end of the second trimester, as soon as her ability to hear sounds in the womb developed. Soon after, she also began to respond to the sound of her father's voice as he began to read to her in his soothing voice while he kept his mouth close to her mother's belly. Although the clarity of such verbiage has been questioned, Maeven responded and turned to the individual voices of her parents almost immediately after she was born.

Maeven's brain at birth will allow her to learn any language and repeat any phonemes that she hears. If she had been born into a bilingual or multilingual family, she would easily learn the languages that were spoken to her. This ability is short-lived. By the time she's a year old, her brain will have pruned away the neurons that were not used. In other words, her ability to hear some phonemes will be gone or at least partially diminished. She will focus on the sounds that she hears, and by approximately eight months, she will begin to attempt to mimic those sounds. Along with the vowels and consonants, she will expressively mimic other phonemes that are available to her developing brain.

Her parents, however, will only recognize the sounds they know. So Maeve may begin to babble a string of sounds like, "ma, ba, goo, eh, neh, un," What her parents (and especially her mother) will pick up is the first sound, "ma." So, she begins to repeat the sound while she beams at Maeve. "Ma, ma, ma…you said my name, ma, ma, ma." Eventually Maeve gets the idea that this particular sound gets a great response from her mother. She will begin to repeat the sound to please her mother and get instant feedback. It doesn't matter that, within her babbling, she may have shared phonemes from multiple other languages. Since those won't be repeated back to her, she won't strengthen the connections for those sounds.

A beautiful melodic dance (called motherese) has begun: parents respond and encourage the phonemes they recognize, and Maeve repeats those sounds that encourage a response from them. Communication is born.

## A Matter of Recycling

Spoken language is natural. Our brain is hard-wired for it. Although the process our brain follows isn't exactly linear, it is a natural process that cognitive neuroscientists and educators have come to understand.

Reading, however, is more a complex collection of abstract symbols that vary in size and shape. Neuroplasticity, our brain's amazing way to change, is key to the complexity of reading. It is a part of our visual system that remains "plastic" and open to the changes that can allow our brain to see letters and connect them to sounds. We can then hear those sound combinations and realize that they create words. And finally we'll connect those words to appropriate meanings. Many researches think of it as a matter of cognitive recycling. The natural and beautiful genetic-driven language pathway creates new circuits along with our visual system and other cognitive systems. The best part: we adults can help.

## A Recipe to Make Readers, You Say? Let Me Offer One Today!

Ingredients:

- A loving and literacy filled environment.
- Caregivers who talk to children many times per day, and listen and respond to them as well.
- Caregivers who read aloud daily to children—and it's more than okay if it's the same book. That's how our brain sees that letters, sounds, and words are repeated and so become meaningful.
- Good nutrition for a strong healthy brain.
- Exercise to help our brain grow and brain systems to synchronize.
- Caregivers who help children play with sounds, such as rhyming (hence, the Dr. Seuss-ish recipe heading above).

Reading is a complex cognitive task. Immediately after our eyes visualize a word, a multifaceted set of physical, neurological, and cognitive processes become active. These enable us to convert print into meaning. Visual nerve impulses stimulate an area near the back of our brain that allows us to see the light and dark areas that define each printed letter on a page. Children initially read pictorially. The letters and words are stored in our brain's picture form area. Another structure of our brain allows us to convert the letters we see into sounds, and then those sounds merge into language. Finally, another part of our brain converts the jumble of words in any given sentence into something meaningful.

The fine work of such gifted researchers as Stanislas Dehaene (2009), Sally Shaywitz (2003), and Maryanne W (2007) now uncovers the complexity of reading. Reading is not a natural process such as speech. It's understandable that some children struggle, since we have no genetic program for reading. Our brain "recycles" neurons from its oral language system to create a reading system. For most children, the process is smooth and unmemorable. For others, it is an uphill climb, as neurons try to distinguish sounds, from one another. Connections struggle to be made. For them, it's like playing a very out-of-tune instrument with unclear rhythm and little synchronicity.

We often listen to the delightful sounds of a language and marvel as a toddler begins to communicate by combining sounds into syllables. This is a natural process, as the hard-wired language system kicks in at birth. It goes from cooing to babbling and on to practicing the sounds that they have been listening to for eight months. At first one wonders what the baby is trying to say, yet the appropriate response from the caregiver involves a smile, a nod, a touch, words, and so on. Conversation has begun!

Think of it as a horse race. The bell sounds and they're off. Some with the speed of a champion. No struggles here. What does that mean? The child has been talked to daily and elaborately. One thousand stories have been read aloud. And the verbal brain structures are developed and ready to go. It's a smooth ride from non-reader to good reader to expert reader.

But what about the less developed brain, the child with no literacy at home, and no one to dialogue with in order to hear the sounds of the language and practice them? The complexities of their reading become more perplexing. Many children from non-literate environments can learn to read easily once we introduce them to phonemic awareness and phonics. Others seem to struggle and, without explicit intervention, may never know the joy of reading fluently and with comprehension.

According to Shaywitz (2003), readers need to be able to do the following five phonological tasks:

- Hear the beginning sounds of words and recognize when words begin with the same sounds.
- Separate the initial sounds of a word.
- Separate the final sounds in a word.
- Combine sounds as in blending.
- Break words into their separate sounds.

In Houston, Dr. Andrew Papanicolau uses MEG (Magnetoencephalography) to look inside the brains of struggling readers (Rezaie, et al., October, 2011). He has found that good readers show more activity in the left hemisphere and struggling readers show more activity in the right hemisphere. Through his research, children are explicitly taught phonemic awareness and phonics with great results.

In a recent study by Wolf, et al. (2012), musical training appeared to increase phonological awareness for children in kindergarten with results seen through the second grade. The more musical and rhythmical training, the more improvement occurred. This is yet another piece of the complexity puzzle. One of the important facets of reading is prosody, that rhythmic reading pattern that adds pleasure and meaning to the process. Can it be that musical training helps train our brain for sound and rhythm?

My recently published book, *Wiring the Brain for Reading* (Sprenger, 2013), provides many additional specific strategies for helping children learn to read successfully. A positive reality about reading is that most primary teachers and schools provide the effective teaching that enhances reading ability. But, no doubt about it, parental help is also critically important.

## Summary

Spoken language is a human quality beyond comparison. It is hard-wired in our brain. That is, specific language areas are already in place and waiting for the right experiences to help them connect. With the proper environment and with the knowledge gleaned from brain research, children can become effective at verbal communication. They can increase their vocabularies and their comprehension of words, so that by the time they are ready to read, they understand that sound combinations can have meaning and affect their lives.

New research suggests that no pre-wired reading pathways exist in our brain. Reading occurs through the "recycling" of neuronal connections. These are recruited to create reading pathways that principally occur within the language pathways. Therefore, it behooves all involved in the reading success of a child to ensure that the language pathway reaches its peak of productivity. The stronger the language pathway, the easier it will be to reuse some of those cells to create a strong reading network within the child's brain.

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## Chapter 5

*(IAE Newsletter #125. See [http://i-a-e.org/newsletters/IAE-Newsletter-2013-125.html](http://i-a-e.org/newsletters/IAE-Newsletter-2013-125.html).)*

# Co-constructed Learning Enhances Understanding

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## The Event

Crossing a stream can be a very complex action.

Katie's foot slipped on the mossy rock, plunging her into the stream. The water was waist deep on me, nearly chest deep on her. She lurched sideways, off balance. She reached out, grasping for anything, terror on her face. The three other teenagers in the party didn't see her desperate moves. Each was wrapped up in a private world concentrating on not being swept away by the cold mountain stream. Katie regained questionable footing and staggered across, collapsing in a wet pile on the bank. Our attention then had a laser focus. We not only didn't hear one another on this first stream crossing, we were barely aware of each other. That stream crossing lesson had lasted less than five minutes.

Our wet miserable group then discussed what happened. Everyone had slipped. The swift water was terrifying. Evan and Jon noticed that the current broke when one person was slightly upstream, making it easier for the downstream person. But tomorrow loomed, with a bigger stream that we couldn't avoid. Further, our food cache was on the other side.

The next morning we resumed the discussion. Jon suggested we move slowly in pairs, holding on to each other. The larger person could break the swift current by just being upstream. There was only one way to find out, and any error in our thought would have immediate negative consequences.

The memory of that first stream crossing remains more poignant than hundreds of subsequent crossings. The lesson had no grades, no binders with strategies, no lecture, no short review for a written test, and no fake reality on a screen. We didn't get to try it repeatedly. It was real, and the lesson has stuck in fine-grained detail for decades. The lesson was experienced with our minds and bodies working together. It was a personal learning experience whose solution was felt. It had personal rather than abstract consequences.

## The Explanation

Here's what we learned by trial and error (and no fatalities). We could project our thinking forward if we debriefed what had happened and engaged in focused reflection that was guided by specific questions. We envisioned ourselves in a similar type of situation, having to determine what we were we going to do. We prospected or searched out what we needed to do differently, and then had an authentic rather than pretend practice with very real personal consequences, including our personal comfort and safety. The combined experiences were then assimilated into our personal history. The experience was far more powerful and memorable than being tested on reading or hearing a lecture. We encountered a complex situation in crossing a stream, and by debriefing it we moved our understanding into a still more complex level.

In simple, linear relationships, a small change can produce a specific result. Reality, however, is made of many complex relationships. As things become increasing complex, more variables simultaneously interact with each other, and predicting a specific result becomes exceedingly complex.

In complex equations, small perturbations can create very different and more complex results. In the stream-crossing example, having one person slightly upstream to break the current triggered a series of events leading to more complex learning. This is an example of the popular but poorly understood concept of "butterfly effect." Minute changes in initial conditions often produce large differences later on. If the initial conditions in a marble spiraling down a funnel change even a tiny amount, the results change. Tilting the funnel ever so slightly or using a marble with a different weight or size results in a completely different pathway.

The same is true when considering the complexities of modern life and the challenges we face daily. In solving complex problems, we need other people to help us expand beyond our own paradigms, and schemas to see more connections. Our assumptions and traditional linear thinking may create roadblocks, becoming the perturbations that can drastically change the result.

The blessing and challenge is that the social nature of complex problem solving impacts both education and the corporate world. We need other people to help us learn and grow neurologically, conceptually, and developmentally. A key part of that learning growth is to respond appropriately to feedback provided by the rapidly changing word. Feedback loops impact complexity and modify the outcome. Just as in the butterfly effect, complexity itself is an evolving equation.

Understanding the underlying problems and projecting them into new situations has practical ramifications, especially for education and management. What starts simply can be rapidly amped up in complexity. Problems are solved when thought reaches a higher level of complexity, grasping new relationships and new principles. The AH-HA moment is a classic demonstration of such increasingly complex thought. Harvard's Kurt Fischer found that the increasingly complex patterns of cognition are best described through dynamic complexity theory (Fischer, 1980). The theory is based upon robust cognitive neuroscience findings that explain and predict how cognitive development progresses with age and is significantly affected by environment using Vygotsky's Zone of Proximal Development (1978). See also Chaliklin (2003) or Wikipedia's zone of proximal development.

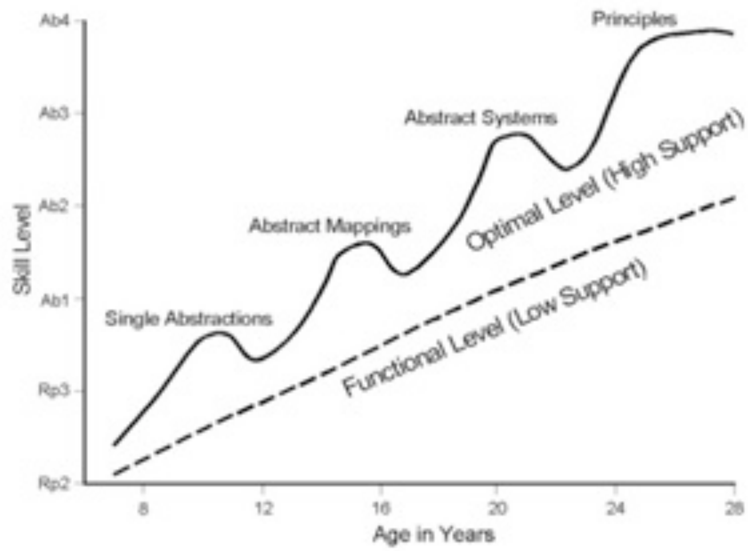


Figure 1: Skill Theory (Fischer, 1980)

Dynamic systems theory has a number of implications for learning, whether in the classroom, field, or in a corporation. In complex, dynamic systems, multiple variables that interact with each other change responses. Rather than producing a simple linear pattern from cause to effect, repeating patterns are created that fluctuate in scale. Some are big, some are small. The same pattern can be found at very tiny scales, such as tree branches forking into twigs, or a much larger scale, such as the tree trunk forking into large branches. So, too, in instruction where patterns repeat within a lesson design or in a whole program. Consequently, a small change affecting the initial pattern on a small scale can amplify the pattern on a much larger scale, the butterfly effect. Fischer found that human thought and cognitive development appear to have such patterns.

## Application

The primary take-away is that predictable patterns to the process of learning and development occur even in highly complex circumstances. Models of these processes are regularly created. Having a model of learning, being intentional with instructional design, and using meaningful feedback loops from the learning event at multiple scales during problem analysis allows one to knowingly influence complexity, as opposed to being at the mercy of it.

Feedback loops can be created at each level of complexity and involve key players in the events or circumstances being analyzed, as exemplified in the stream crossing. This means that a classroom or corporation can insert specific feedback points to gather good data. In the stream crossing, the guided reflection after the first crossing yielded crucial data. The feedback loops at specific but multiple points during the learning event yielded timely information and helped to inform precise changes that facilitated achieving the learning goal.

Awareness of where the learning will go next helps teachers, trainers, and corporate managers know how to use the data gathered from the feedback. Additionally, understanding how specific feedback and the data from it fit into the larger scheme of complexity allows for greater implementation and integration of identified steps or proposed changes.

To model these dynamic interactions, we conceive of the natural dynamic of learning as a fractal spiral that connects distinct yet interdependent brain processes in an intentional sequence. While each step is connected in a dynamic, fractal manner, integrating and building upon pervious steps, the sequence accommodates for natural bottlenecks such as cognitive load and neural growth stabilization. The spiral illustration shows how complexity, imbedded with different instructional phases, leads to new, more complex solutions.

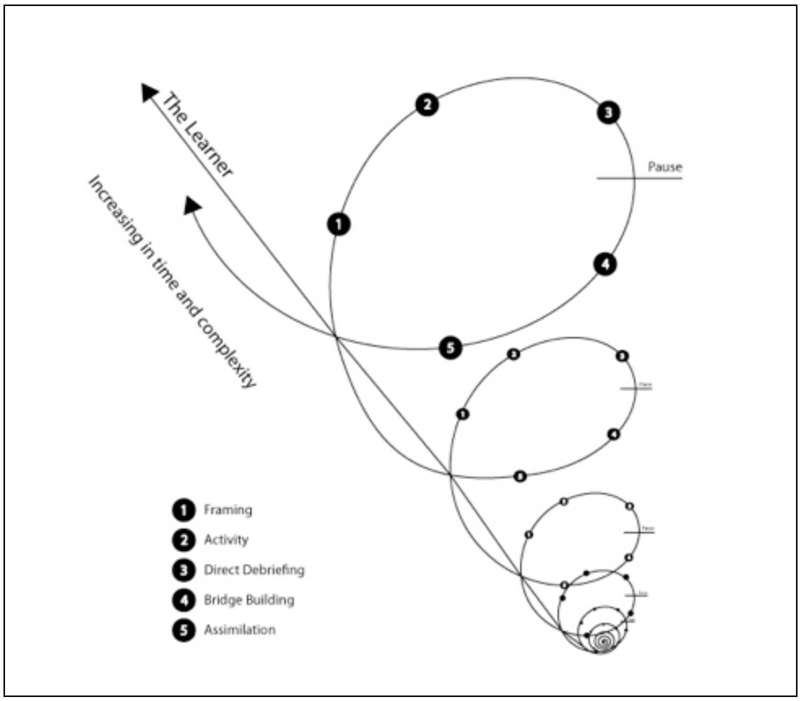


Figure 2: Co-Constructed Developmental Teaching Theory

Each spiral with the sequential numbers represents an increasingly complex learning event. Internal feedback loops (not shown in the illustration) can link to any point from another to inform the learning. Like the marble and funnel, such feedback loops can potentially alter the path of learning, the players, and their actions. In a learning event there are five numbered actions shown in the above illustration. These are framing, activity, direct debriefing, bridge building, and assimilation. Each is dynamically linked, and hence highly adaptable to the changing circumstances. This means that the five instructional actions, including a neurologically critical pause that helps establish new linkages, are scalable. They work at any level of complexity.

In the stream crossing, the students started at one scale, went through all the phases of the learning event as a group and emerged with a deeper and more complex understanding of how to cross a stream. Both the leader and students co-constructed the principles involved in complex problem solving. Those principles were assimilated and used to inform their actions in the next learning event, whatever circumstances arose.

Understanding the nature of complexity, where a slight change in any one of a multitude of variables can substantially change outcomes, allows for the design of more effective learning events. Cognitive research increasingly points to the role others play in our learning and development and the need of others to help advance our thinking. This creates obvious questions about the future of learning in a more digitized world. What level of interaction and co-development can come from a computer? What does this mean for isolated and individualized computer-based training? What does it mean for business environments where collaboration and analysis of the decision-making process are not allowed?

By developing a better understanding of the brain and how its dynamic systems interact with their environment, we can design and deliver better learning events in a highly complex world. Such intentional designs can potentially reduce assumptions and guessing while scaffolding better solutions to emerge in an uncertain world.

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## Chapter 6

*(IAE Newsletter #118. See http://i-a-e.org/newsletters/IAE-Newsletter-2013-118.html.)*

# Spontaneously Clarifying Complexity

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## A Sudden Realization

As a young teacher, I wondered if many of my students were unwittingly acting out suggestions given to them by authority figures during natural moments of high suggestibility. *Eureka!* It's just like hypnosis. This sudden realization led me through a Ph.D. dissertation (Rousell, 1991) and to a university position. Now it's leading me further into the cognitive complexities of personal development and life-changing moments.

The actual story below illustrates a common event that parallels the hypnotic process. Cathy, a graduate student and veteran teacher, recalled a profound moment that I would later call a Spontaneous Influence Event (Rousell, 2007).

Cathy's faith in her capability had plunged considerably by the time she reached the fourth grade. She felt like the *dumb* kid in class. Efforts to excel only reminded her that she was a failure. She discounted occasional successes by attributing them to luck, not ability. She felt hopeless, avoiding any effort, afraid that attempts on her part would only confirm her feelings of inadequacy.

A life-changing event occurred while playing Monopoly with her favorite uncle. He casually asked Cathy how she was doing in school. She burst into tears. She described how she felt dumb and frustrated with school. She wondered if she would ever add up to anything worthwhile. Her uncle then told her something that she would remember vividly for the rest of her life. He said, "Someone who struggles so hard with school will make a great teacher. Discouraged students need a teacher like you." This simple statement stunned Cathy, instantly changing her mind-set.

It doesn't necessarily follow that those who struggle at school will become good teachers, but the comment did spur Cathy on, and that's the central issue.

Cathy retrospectively noted that she, her parents, teachers, and friends hadn't noticed a conspicuous change in her behavior, but her inside world profoundly transformed. Before that event, school aroused feelings of weakness and incompetence; it now awakened a sense of challenge. Schoolwork changed from an unattainable task to an ordained rocky pathway on her journey to become a teacher.

Something triggered a moment of high susceptibility to suggestion whereby Cathy automatically and unconsciously accepted her uncle's assertion that she'd be a great teacher. This became a self-affirming mindset that colored her view of herself and her experiences. She began acting *as if* her new mindset was authentic. What was it about this ordinary event that created such a profound effect?

## To Find Enlightening Answers, Formulate Instructive Questions

My graduate program led me to hypnotic susceptibility as a major factor. My studies concluded that the conditions for hypnosis are regularly and substantially present in events such as those experienced by Cathy. I thus needed to generate a thorough cognitive and neurological model to explain how and why these spontaneous transformative events take place. As indicated above, hypnosis was my initial explanatory model but it proved unsatisfactory because teachers don't really hypnotize their students in the traditional sense. Importantly though, I discovered that all of us experience natural spikes in susceptibility to suggestion that are similar to the heightened suggestibility induced in hypnosis. During these moments, we may profoundly change a mindset that in turn generates a dramatic shift in a belief. This is what happened to Cathy. Current models better explain how and why these events occur.

### Thinking Fast and Slow

The cognitive processing of strong emotional events typically occurs outside our conscious awareness and rational processing. In his recent book, *Thinking, Fast and Slow*, Nobel Laureate Daniel Kahneman (2011) dichotomizes our cognitive mechanisms into two systems he names System One (quick and automatic) and System Two (slow and effortful). Regarding surprise he states, "Surprise then activates and orients your attention: you will search your memory for a story that makes sense of the surprising event." He describes how impressions made by System One during surprising events often turn into your beliefs that in turn become the source of the impulses for the voluntary actions made by System Two. In Cathy's case, her uncle's comment stunned her; she accepted the literal message without rationally disputing it. If she hadn't been stunned, her I'm-not-good-at-school mindset would probably have dismissed her uncle's comment as sweet, but empty, praise from a loving uncle.

### Surprise Activates Revision Impulses

Our brain evolved to adapt to expected regularities, and to focus on events that surprise us (Itti & Baldi, 2009). Surprise suggests that something significant has happened. Our heart rate increases, attention becomes riveted, and adrenaline encodes subsequent interpretations with a neurological highlighter. Surprise is perhaps the most important causal precursor of belief change (Lorini & Castelranchi, 2007). The main effect of surprise is revision. We must either revise our knowledge of the environment or our beliefs about ourselves. In Cathy's case, her uncle's surprising statement generated a revision impulse. His statement provided a positive frame for the instant accommodation of a new mindset. This new mindset triggered the activation of underground emotional machinery.

### Underground Machinery: Emotions and Tags

The emotional contribution to mindsets displays itself quite demonstrably in the framing effect (Goldberg, 2009). Think "glass half full" or "glass half empty." If Cathy feels weak at school, academic struggles are cognitively framed as "glass half empty." Once Cathy reflexively accepts the comment, "Your struggles with learning will make you a great teacher," academic struggles are now cognitively framed as "glass half full." It creates a positive emotional tag. Damasio (2003, 2010) refers to this as a "somatic marker." Cathy then *feels* that working hard to overcome deficits is the tell-tale sign of a successful teacher. This half-full perspective or yes-I-can mindset triggers an optimistic outlook that in turn allocates more cognitive resources. A cascade of subsequent behavior thus generates a self-fulfilling prophecy. Cathy subsequently responds to learning struggles as engaging challenges.

### Attention and Perception Mechanisms

Cathy's new mindset trains and restructures the cognitive networks. The predictive mechanisms of the brain play a huge role in determining what we attend to and thus, what we perceive. In other words, Cathy used to attend to signals that affirmed her hopelessness. After her uncle's comment, her cognitive mechanisms now prime her to attend to signals that affirm accomplishments through hard work.

### An Interesting Speculation about the Role of Brain Lateralization

Goldberg (2009) illustrates how our brains' hemispheres evolved to specialize in particular tasks. Our cerebral hemispheres have complementary processes. The hemisphere that specializes in a task (such as handedness) may vary from person to person. For most humans, the right hemisphere is organized to effectively interpret and creatively respond to unfamiliar challenges. The left hemisphere is organized to identify familiar challenges and then to activate effective responses. The right hemisphere's neuronal systems are thus broadly connected to permit the consideration of many alternatives. The left hemisphere's primary task is to activate established routines. During an unfamiliar event, the left hemisphere has no routines to activate. The right hemisphere thus generates a response. If the response works, it eventually becomes adopted by the left hemisphere and is automatically applied in similar situations. It thus becomes routinized.

During her uncle's remark, "Someone who struggles so hard with school will make a great teacher," Cathy's left hemisphere (that specializes in routine) had nothing to activate. It didn't have a "Cathy-will-make-a-great-teacher" story. Her uncle's remark triggered the right hemisphere to generate a new response. The new response from Cathy, "I-will-become-a-great-teacher," strengthened through self-affirming evidence generated by her new attentional and perceptual shift. This new response triggers underground mechanisms to instinctively scan for evidence that confirms this new perspective. This new perspective then routinized to the left hemisphere as the new mindset.

## Codify What You Learned and Make it Operational

Over the years, I've examined hundreds of life-changing anecdotes. Clear patterns appeared. Positively framed comments that surprised the recipient turn up regularly in these stories. Cathy was surprised by her uncle's comment. The structure of his statement is also a critical factor in her mindset transformation. He named some skill, disposition, or quality that was already present and then linked it into a forecast. Cathy's uncle connected her current experience, "Students who struggle with learning," to a desired result, "will make a great teacher." This communication pattern also appears regularly in my research.

I teach this simple structure to my pre-service teachers. The structure has two elements:

1. Create an element of surprise with the content or the timing of the comment.
2. Name a skill or disposition and express the result it will create.

The following example from a pre-service teacher illustrates both elements.

> Nevil is a very creative student. He plays music, acts, and draws pictures on all his assignments. He sometimes questions why we are doing a particular assignment, especially when there is a lot of writing involved. One day when he complained about a particular writing assignment, I told him, "Your ability to put creativity into everything

you do should make this one a breeze!" The piece he turned in was very creative and by far the best writing I had seen from him.

My own sudden developing awareness of the complexity of a "life-changing-moment" generated a 30-year search for the mechanisms at play. I'm encouraged to see a new generation of pre-service teachers who are now aware of the fragile emotional state of their students and cognizant of a productive communication pattern. I'm also excited to teach a simple, yet powerful, mechanism for the intentional production of positive and resilient mindsets in our youth.

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## Part 2

# The Underlying Base of Complexity

Mastering concepts, the essence of understanding, begins with analogical thought, the cognitive property that separates humans from primates and social mammals. Analogies search for relationships between a currently unknown concept and something that has some of the understood properties of the concept. The childhood analogy of Santa Claus thus morphs into a realization that gifts come from the family, into helping out friends, into adult philanthropic behavior. Analogies spark scientific, technological, cultural, governmental, and other explorations of complexity. The six chapters in Part 2 explore the varieties and extent of analogical thought and the nature of knowledge itself.

## Chapter 7

*(IAE Newsletter #121. See http://i-a-e.org/newsletters/IAE-Newsletter-2013-121.html.)*

# The Central Roles of the Varieties of Analogy

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Concepts are evolving fluid entities. Do those five words (each of which is itself a concept) adequately explain what the entire set of words conceptually means? Probably not.

Thought requires concepts, and analogies are perhaps the best way to gradually understand a concept. Analogical thought identifies and uses common elements between an understood concept and one that isn't yet understood.

Thus, the analogy a heart is like a pump can help children understand what a heart does to maintain blood circulation if they have seen and understand what a pump does to regulate water circulation. Hearts and pumps aren't the same thing conceptually, but they can be analogous to each other. The human ability to understand, create, and communicate analogies is perhaps our greatest cognitive property, since analogical thought provided the basic creative spark that led to advances in science/technology/the arts/religion/government/etc. See http://en.wikipedia.org/wiki/Analogy.

## Sour Grapes

Many children's stories/fables/parables/proverbs/myths/scriptures/etc. are analogous because children have to develop an understanding of many complex and often moralistic concepts. Aesop was a Greek slave who lived 2500 years ago (Aesop, BCE). One of Aesop's better-known fables helps to explain a complex mental concept that social psychologist Leon Festinger further explored 70 years ago via his cognitive dissonance theory: the inner tension we feel when we're trying to reconcile two conflicting cognitive thoughts. We normally resolve the conflict by modifying one of the conflicting states and then creating a justification for our subsequent behavior (Festinger, 1956).

Here is Aesop's much simpler analogical explanation of the implied cognitive dissonance situation: A fox tried unsuccessfully to reach some grapes. After failing and giving up, he said to himself that the grapes were probably too sour to eat anyway.

The fable is often told to children as an introduction to the ways we humans confront rejection, one way being to convince ourself that we didn't really want the sought for reward anyway. Rejection is an issue we often confront in life when we don't get a toy we want, don't get selected to be on a team, are rejected for a job, or don’t get a promotion. The fable is so well known that most folks immediately understand the analogy of sour grapes as describing how we often rationalize rejection.

Other related well-known analogies can add to the subsequent understanding. For example, the optimistic “There's a silver lining,” “Count your blessings,” or “That's the breaks” layer on other analogies that can amplify sour grapes. Actually, much of our common discourse involves strung together sequences of analogies that we automatically connect to basic concepts to help in understanding even more complex related concepts. Our brain thus converts folk knowledge into complex cognitive concepts.

## Analogical Books

Douglas Hofstadter and Emanuel Sander (2013) have written a sprawling book on analogies, *Surfaces and Essences: Analogy as the Fuel and Fire of Thinking.* It certainly covers everything anyone could possibly want to know about analogies. The almost 600-page book can have a wonderful appeal for those who professionally teach, speak, or write. The authors' extended explanations of analogies and related concepts continually sparked further thoughts in my own mind.

Another more accessible book that makes heavy use of analogy is Thomas Armstrong's *The Human Odyssey: Navigating the Twelve Stages of Life* (2007). In explaining the complexities of life's various stages, Armstrong draws on many wide-ranging analogies that explain the complexities of the life stages that readers have yet to experience, or early life experiences they may have forgotten.

I've probably gotten to my final life stage, and can report that Armstrong's analogies seem to me to be quite well drawn. For example, many world myths involve infants being sent down a river to be reared by others, and Armstrong writes of the post-conception fertilized egg that travels down the Fallopian tubes towards the complex ocean of life.

## The Cultural Need for Analogies

Analogies seem to automatically connect to concepts a person already understands, and this capability is very important for children who currently understand a limited number of basic concepts but need to amass many thousands more, and still lack the cognitive skills to logically make connections. Try it: What visual thoughts automatically come to your mind when someone tells you about a computer addict who tried to get rid of a fly that landed on his screen by clicking on the fly and dragging it off?

Aesop lived during the BCE years, when analogy was almost the only way to adequately explain the natural world. So fables, parables, myths, and scriptures explained nature and its human response for many millennia. During the past few hundred years, scientific and technological advances have moved us towards a deeper understanding of complex physical and biological concepts. The analogies had suggested an approach for more careful, scientific exploration of the phenomenon.

Many folks are uncomfortable with the developing scientific concepts. They still prefer the scriptural and mythic analogical explanations that they grew up with. I guess it's OK because without these historic lead-up analogies we humans probably wouldn't have used our imagination to develop the scientific and technological advances that can get us beyond them.

Mind and brain provide good examples. Mind arrived first, a disembodied analogy to explain rational thought. During the past century brain increasingly became the conceptual reality of what folks formerly thought the analogical mind is supposed to do. Cognitive neuroscience is now progressing so rapidly that mental analogies that once seemed beyond scientific analysis are now being scientifically explained with increasing credibility as brain phenomena.

Consciousness and morality are good examples. Cognitive neuroscientists search for the brain equivalents of what had been a mental (philosophic and theological) phenomenon for millennia. It's simply amazing what scientists have learned about the underlying biology of consciousness and morality during the last 30 years (Sylwester, 2013).

Mind and brain (like heart and pump) aren't necessarily the same phenomenon, although some influential folks still think they are (Brooks, 2013).

This doesn't suggest that mind is a negative construct, but rather that the scientific community now celebrates it as a necessary analogical phenomenon to prime the pump (analogy alert) towards the imaginative scientific search for the real concept of what a brain actually does. Further, those who think that machine consciousness is a probability are pushing towards an extended expansion of the concept of brain.

Perhaps some phenomena exist (such as beauty, love, and god) that are genuinely beyond scientific exploration and can thus exist only as analogy. The issue is whether that would be because they are actually beyond scientific exploration or because of the way we've historically defined them.

I think it's the latter. The powerful defining human verbal analogies go back well before science, and as suggested earlier much of the arts is analogical. The scriptural parables and mythic fables thus sparked artistic analogical representations, and science eventually emerged from them. As suggested above, some religious folks are so caught up on the conceptual reality of their analogies that they're willing to wait for a celestial afterlife to get to the real concepts. In the meantime, they often decry the wonderful scientific discoveries that emerged from their own analogies—discoveries that are already moving them in the direction towards conceptual understanding.

Given the complexity of contemporary human life, it's important that educators explain the varieties of analogy and the role that they play in helping our society move from "it's kind of like this" thinking to a clearer understanding of conceptual reality.

## From Analogy to Concept to Intelligence

What is intelligence? Is it the number of concepts we know and can use? Not really.

Hofstadter and Sander (2013) suggest (seemingly with tongue firmly in cheek) that most of the many theories of intelligence:

> …hover near it but fail to pinpoint the core of intelligence; they don't get near the heart of the matter, let alone hit the nail on the head. Never quite managing to put their finger on its essence, they merely skirt the crux, flirt with the nub, and miss the gist, curiously unable to zero in on the kernel of the phenomenon of intelligence.
>
> Intelligence is rather the art of rapid and reliable gist-finding, crux-spotting, bulls eye-hitting, nub-striking, essence-pinpointing. It is the art of, when one is facing a new situation, to swiftly and surely home in on an insightful precedent (or family of precedents stored in one's memory). That, no more and no less, is what it means to isolate the crux of a new situation. And this is nothing but the ability to find close analogies, which is to say, the ability to come up with and use strong and useful analogies.

So that's what intelligence is. Either that or else something like it.

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## Chapter 8

*(IAE Newsletter #122. See http://i-a-e.org/newsletters/IAE-Newsletter-2013-122.html.)*

# The Role of Caricature

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Caricature and other forms of humor quickly get to the essence of understanding and diffusing complex issues. That's probably why folks who do this effectively play such important societal roles.

Comedians, cartoonists, and viral videos on the Web often ridicule poorly thought through political and cultural proposals. Their analogical ridicule then frequently gets more attention than the original proposal. When Obamacare became the morphed version of the Affordable Care Act, it switched attention from national health care to presidential hopes. The presumed existence of Weapons of Mass Destruction was a principal impetus for the Iraq War, but when none were found, their existence was ridiculed as an example of a presidential fiasco.

The previous chapter synthesized elements of Hofstadter and Sander's monumental work on analogy, *Surfaces and Essences: Analogy as the Fuel and Fire of Thinking* (2013). Thought requires concepts, and analogies are perhaps the best way to gradually understand a concept. Analogical thought identifies and uses common elements between an understood concept and one that's not yet understood. Using a water pump to explain a heart is a good analogy because the key mechanism in both pumps and hearts regulates the flow of liquid. A person who understands how water gets pumped technologically can thus move towards understanding how blood flows biologically.

This illustrates one of the difficulties in teaching. Each student has a unique background of knowledge and skills. A teacher and instructional materials try to explain new concepts using analogies based on knowledge all students are assumed to have. But, some don't have it! This is especially true in teaching a group of students with mixed languages and/or from differing cultural backgrounds.

## Successful Comedians and Cartoonists

What successful comedians and cartoonists do with ridicule is to create a caricature of a current situation. Although their exaggerated simplification of the issue (that starts the laughter) might initially seem superficially incorrect or unfair, effective caricature either actually represents the central issue or at least nudges people into thinking that it does. Caricatures of issues work best when they represent the emotions of the audience through an unexpected analogy that immediately resonates. A straightforward analogy is too bland for the passionate. They want their criticism to go to the edge and to analogically highlight the elements that sparked their passion.

For example, late night comedian Jimmy Fallon took on both Presidents Obama and Bush in a simple caricature that encapsulated very complex governmental responsibilities. He suggested that the almost $900 billion health care act is about 2000 pages long, and so it cost about $2 million per word. Fallon suggested that these were the most expensive words to come out of Washington, D.C., since George W. Bush's "Mission Accomplished" speech given on May 1, 2003.

## Caricature and Political Power

The U.S. is a secular democracy. Because a secular democracy was a new concept in 1789, we had to design it ourselves. No monarch or state religion would exist, and majorities of free white male property owners would determine legislation and administration. Courts would insure individual rights. Still, power could move towards a relatively small group of wealthy people and/or those who controlled powerful cultural organizations.

The updated medieval English Court Jester could perhaps become the solution for those who lacked political power—such as women, non-whites, slaves, the young, and the poor. Wealth and organizational leadership can provide power for the few, but the few will still have to get the majority of the rest to vote for them. Widespread ridicule within the disenfranchised is thus a powerful antidote for political pretensions and abuse.

Fast forward to the 21st century and a national population of 300 million. The various forms of social media have further elevated the importance of contemporary Court Jesters to rapidly shape opinion and to strike fear into the hopefully powerful. Politicians who might otherwise say one thing to one group of voters and the opposite to another have learned the truth of what comedian Jon Stewart said, "Don't they know that we tape everything, and we never erase the tapes?" Control problems still remain 200+ years later, but the powerful white male property owners who controlled things at the founding of our country are encountering more and more opposition.

## What Makes Caricature Effective?

Assume a political or cultural proposal with potential problems. If the problem is systemic, the caricature should get to the heart of the problem. If the systemics of the proposal are OK but the proposal doesn't consider the possible negative effect of variables, the caricature should be directed at an example of an especially vulnerable variable. It's frequently possible to argue both sides of the same such issue with almost identical analogies. For example, consider these two bumper stickers: "Work Harder: Millions on welfare depend on you" and "Work Harder: Wealthy people need their tax breaks."

Caricatures either seek to ridicule structural or superficial features of the proposal. A structural feature is something that defines the category itself (the purpose of immigration). A superficial feature refers to things that can be modified without necessarily affecting the function of the category (immigrant selection criteria).

Since many societal problems are now too complex for an average person to understand, caricature as a form of analogy frequently begins by ridiculing superficial features. For example: "Annoyed by immigrants? Tell it to the Indians." One might think that this is a negative approach for making a point when human cognition is basically about thoughtful analysis. Nobel laureate Daniel Kahneman (2011) begs to disagree. He defines two systems we use to determine decision and consequent behavior. Emotion is a primitive evolutionary system that allows us to rapidly size up and then respond to a situation. The second system, inferential reasoning capability, came along much later and requires an advanced understanding of the issue and rational thought prior to decision and response.

Experts thus see features of an issue that novices either don't see or don’t know how to interpret. To the extent that Jesters can insert the essence of depth into surface features, they help the naive to get into the structural issues without extensive initial study. The opposing side also has its Jesters. Democracy rests on the ability of voters to attend to both sides before arriving at a decision. So maybe it’s the Jesters and the political artists who have now most increased their political power in an electronic age.

The fact that we're a secular democracy with a strong scientific focus has caused a rift. Both religion and science are currently seeking increased political power. Church and science differ in perspective and in the way they validate claims, so it shouldn't come as a surprise that the Jesters have entered the caricature fray on both sides. For example: “This scientific paper contains much that is new and true. Unfortunately, that which is true isn't new, and that which is new isn't true.” Another is: “Don't pray in my school and I won't think in your church.”

Given the increased impressionistic availability of caricature in social media, it becomes even more important that educators help students learn to understand the role of caricature in analogical thought.

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The documents listed below are for this particular chapter. References from the individual chapters have been collected in the References section at the end of the book.

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**Chapter 9**

*(IAE Newsletter #124. See [http://i-a-e.org/newsletters/IAE-Newsletter-2013-124.html](http://i-a-e.org/newsletters/IAE-Newsletter-2013-124.html).)*

# The Complexity of Humor

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**Teachable Moments Publishing**

**Posted in classroom:**

> Dear Students,
> I know when you're texting in class.
> Seriously, no one just looks down at their crotch and smiles.
> Sincerely, Your Teacher

When used skillfully and for the right purpose, humor can be an effective educational tool in the understanding of complex problems. However, some forms of humor, such as pure comedy, typically serve no educational purpose. In contrast, well-constructed and well-facilitated humor has considerable potential to enhance learning. Humor is complex, and must be understood in order to be used effectively.

Humor differs from laughter. Laughter is a physiological expression that may result from humorous reactions, but humor is not necessary to elicit laughter. Similarly, not all humor leads to laughter.

Both humor and laughter can occur privately or socially, but of the two, only humor is cognitive. In fact, Clarke (2009) considers humor "…less a source of jocularity than a stimulant to cognitive activity…an information-processing system."

In addition to being cognitive, humor in an educational environment is a complex social experience. It involves every person present and involves both sending and receiving the humorous "intervention." If sent with malice, one should expect the humor to backfire. If received differently than intended by the sender, again, expect a less-than-intended result. Just as Sylwester (2013) wrote in his discussion of caricature , "This illustrates one of the difficulties in teaching." In this case, the educator must consider the particular reason for using humor, as well as the complex reality of each student's existence within and outside the classroom as a unique receiver/interpreter of the humor attempt.

Used ineffectively, humor can lead to mistrust and lack of respect. Used effectively, however, countless examples have demonstrated that humor can enhance relationships, build social cohesion, and stimulate effective learning. Understanding three basic humor theories may contribute to one's confidence when using humor in an educational setting.

## Three Humor Theories

Bardon (2005) states that, "Humor theory is an interdisciplinary field that demands contributions from cultural studies, history, sociology, psychology, neuroscience, and evolutionary biology, among others." Three long-standing theories—Superiority, Incongruity, and Relief—serve as a reasonable foundation.

### Superiority Theory

Superiority Theory began with laughter. It emerged through the teachings of such notable philosophers as Plato, Aristotle, and Hobbes, who had long-considered laughter as a demonstration of one's superiority over others. In 1900, French philosopher Henri Bergson suggested, rather, that laughter is "a kind of corrective to ways of thinking and acting detrimental to the greater good" (Bardon, 2005). Contrary to Plato and Aristotle, who devalued humor and laughter, Bergson appreciated the comic and saw at least some positive social purpose in laughter. In addition, Bergson introduced the idea that amusement is a cognitive, rather than an emotional state.

### Incongruity Theory

Incongruity Theory argues that, "Humor is found primarily in an intellectual recognition of an absurd incongruity between conflicting ideas or experiences" (Bardon, 2005). Kuiper, Martin, and Olinger (1993) discuss humor as a useful moderator of incongruities.

Comedy writer Greg Dean (1999) teaches that great comedy occurs in "The Gap" between an individual's or group's real or perceived "reality" and a contrasting real or perceived "ideal." Let's say, for example, that students are particularly anxious about an upcoming math exam. The Gap model can help them reduce their anxiety by humorously playing with the reality/ideal situation prior to the exam. For example, one student may consider her "reality" as, "I feel stupid about math," and her "ideal" as, "Math is only for smart people." Encourage your class to play in the mental space (or gap) between "real" and "ideal" and to have fun doing it. The student in the example above might then think, "If I'm so stupid, then why do so many supposedly 'smart' kids ask me to help them with their English papers?"

By humorously playing in The Gap, our mind is playfully forced to find resolution between two incongruent conditions—two "realities" that cannot occupy the same cognitive or emotional "space," yet are inescapably thrust together. The tension created cannot be resolved without something else stepping in to complete the mental dilemma. Humor (often accompanied by a chuckle or laugh) is a healthy method that we humans have developed.

### Relief Theory

Relief Theory further explains that very physiological reaction to the incongruity. This theory, made popular by nineteenth century philosopher and biological theorist Herbert Spencer in *The Physiology of Laughter* (March, 1860), introduced laughter into a humor theory. He notes the many ways in which we store and physically release excess nervous energy. He thus argues that "Laughter is a physical manifestation of the release of nervous energy" (Bardon, 2005).

Nilsen and Pace Nilsen argue that Incongruity Theory is useful to educators. In an incongruent situation, whether verbal/auditory, visual, or cognitive, "We feel tension until we put things right—at least in our mind's eye" (Nilsen and Pace Nilsen, 2013). The element of surprise, a component of this theory, helps to explain how and why humor works to stimulate our mind, while the incongruity resolution process fosters actual learning (Rousell, 2013).

## Humor in Practice

Consider the personal value to an individual teacher:

On July 11, 2009, Taylor Mali posted a passionate YouTube video intended to motivate educators to value their intrinsic role as influencers of hearts and minds. See http://www.youtube.com/watch?v=fuBmSbiVXo0&feature=related.

While most viewers commended Mali for his keen articulation, one viewer commented in part: “Chances are, those teachers you say are ‘shitty’ were once very eager to teach but have taken so much bullshit from arrogant assholes and horrible students that the flame died out.”

Indeed, many teachers do leave the profession because of “burnout.” In addition to stressors, many teachers simply get bored by their own approaches to the same subject matter, year after year.

Humor can be a useful survival skill to help individual educators to reduce stress, keep problems in perspective, keep oneself ever-learning, and remain appreciative of becoming an educator. Coping humor enhances mental health (Martin, Kuiper, Olinger, and Dance, 2009). “Gallows humor” is one type of coping humor. It can be considered highly inappropriate if shared outside one’s immediate circle, yet can help a person reframe and move forward in a healthier frame of mind. For example, after a particularly difficult day dealing with several parents, one administrator told a colleague, “It’s days like this that make me wish I were teaching in an orphanage.” Not a terribly noble comment under normal circumstances, but given the day—and given that the comment was made far from students’ or parents’ ears—an appropriate example of gallows humor.

## The Value of Humor to the Learning Environment

By integrating humor, educators keep the learning environment creative, spontaneous, and fun. Within the learning environment, countless humor techniques can be used creatively to provide tremendous insight into students’ thinking and understanding. And while humor is a cultural construct, it also can be helpful to bridge cultural differences.

In *Humor across the Disciplines* (2013), literature professors Alleen Pace Nilsen and Don Nilsen presented several generational incongruities. For example, on a pie chart titled, “Today’s use of a semicolon,” a sliver was colored orange, and the balance of the chart was blue. The key indicated: orange = “To separate sentences” and blue = “To make winky faces ; ).”

Pace Nilsen and Nilsen understand that humor functions on at least two levels in the classroom: psychological (e.g., to amuse, to test limits, to bond socially) and intellectual (e.g., to teach, to make connections, to compare ideas and concepts). Additional scholarship has identified further functions, which, simplistically, can be summarized by the acronym, PEPSIs: Physiological, Emotional, Psychological, Social, Intellectual, and even Spiritual. Given the sender/receiver relationship with humor and the interdisciplinary nature of the intervention, one can understand the complexity of humor in the learning environment!

## Special Attention

Initially, humor can be tricky in a multicultural classroom. The context of the humor may not be understood. Students' backgrounds may not have prepared them for how to reciprocate light-heartedly to a humorous intervention. Humor in a group requires a considerable level of trust. Still, when used appropriately, humor can be used as an effective tool to break through cultural barriers and to build trust.

The key is to: apply humor for the right reasons, be keen to facilitating for positive outcomes, and constantly build humor skills that will enhance learning.

Given the holistic nature of humor, educators should remember that humor, used appropriately, serves as a tremendous teaching tool. Two international associations lead the study and application of humor: the International Society for Humor Studies (www.humorstudies.org) and the Association for Applied and Therapeutic Humor (www.aath.org). The two websites will lead you to useful resources. Given the complex nature of humor, but also its great potential, professional educators should seriously seek to enhance their own study of how to use humor effectively.

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## Chapter 10

*(IAE Newsletter #129. See http://i-a-e.org/newsletters/IAE-Newsletter-2014-129.html.)*

# Using Theatre Education as Sophisticated Play and to Embody Cognition

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Theatre is a very important and complex human endeavor. As an art form, theatre has historically added a thoughtful, sometimes provocative level of sophistication to the concept of play, play in which the initial informal moves toward understanding and mastering complexity have typically begun. And in doing this, it has spanned millennia from amphitheater to opera to pageantry to proscenium to film to radio to television to YouTube. All these modes of theatre are live enactments by actors at some point in the playmaking process, even when distanced by media technology. Like a child playing out experiences yet to come, actors and theatre artists are at play, working to make sense of the complexity already here. Theatre is thus simply sophisticated play.

### *Charlotte's Web*

When creating formal theatre in Theatre for Young Audiences (TYA), I have often been asked as a professional theatre artist to direct stage adaptations of E.B. White's *Charlotte's Web* (1952). I recently staged my sixth production of the popular stage adaptation by Joseph Robinette (2008). I never say no because I have a deep affinity for this modern narrative classic, and it's fun to escape the university to work with career actors whenever I can. There is more to my story, so let's go back to early in my career.

I spend my summers in Wisconsin near a small rural burg. A sign on the downtown one-room library says, "Open when the librarian is in." When I approached one morning, the librarian was locking the front door and about to leave. I rushed over and pleaded my case. She said she was going over to the elementary school a block away to bring back a class of third graders for a reading fair. She told me go in and she would be right back. She locked me in and off she went. I found a copy of *Charlotte's Web,* sat in a way too small chair, my knees up to my nose, and read quickly. I had read the book when it first came out, so I was thinking about staging possibilities as I scanned through the chapters.

As I reached the dramatic heart of the piece in which Charlotte tells innocent young Wilbur that she is about to die soon, my reading slowed as I automatically took time to "live in" the story. I didn't even notice that the small library was now abuzz with third graders searching for books. Just after Charlotte died alone, I noticed a boy looking right at me from about six feet away. He seemed concerned and a little scared. I then realized that I was crying, tears coming down my face. Here I was, a grown man, sitting in a ridiculously small chair, looking at a nine year old and crying. I immediately became self-conscious and my emotional connection paused. But the boy didn't move, as if waiting for me to explain. The only words I could muster were, "Charlotte died." I held up the book. The tears returned, though stoically. Nearly without pause and with great courage the boy walked to me, put a comforting hand on my shoulder and said, "It's OK, she dies every time."

## From an Event to a Career

This early career event helped me to understand the powerful ways in which literature and art linger for us after experiencing it. This also occurs in live theatre, which is temporal and lingers in us only as an embodied memory. Here's what occurred: A young boy at a reading fair comprehended the complexity of my feeling state and my pain in response to art. He then understood his need to empathize an adult's behavior through an act of genuine caring. He was inspired by the maturing courage of Wilbur and the selfless compassion of Charlotte. And he took the risk to reach out. Why did he do it?

Iacoboni (2008) suggests the boy's impulse to imitate fired in his brain causing his social mind to imagine a re-experiencing of related memories. This reconstruction is virtually relived and performed live in us "as if" our body and brain were experiencing it for the first time, like experiencing live theatre. Because this performance is embodied, the boy used this "as if" experience to understand what is happening in the minds of others and to predict and to simultaneously anticipate what the appropriate action should be in response. Moral reasoning and judgment live and mature at this intersection.

This all happened in the blink of an eye. Can the act of reading narrative literature cause all this? Or, is it because, like live theatre, we are innately wired to perform reenactments of our past experiences "as if" they were happening for the first time now. When my students attend live theatre, they are in fact cast in the show. Hence, participating in live theatre comes with interpersonal and cultural responsibilities. Live theatre is dependent on the concepts of intimacy and immediacy (Machon, 2013). Like our social minds, live theatre demands an intimate and immediate response to "live in" actions on stage. This is what is happening in life in the millisecond before we must act for real, but in theatre we are safe to live in the moment without real risk—a process we call the willing suspension of disbelief.

When reenactments of previous experiences happen in an embodied mind, such as in childhood play and in theatre, memories often merge, shuffle, and transform. New configurations emerge, new possibilities, new hopes, and creativity surprises. Theatre is simply sophisticated play, but in an art form that seeks to unravel the most complex circumstances of living. The work of the theatre artist and theatre educator is anything but simple in revealing meaning.

Where literature is likely to fall short as a way of knowing, and where theatre education is likely to succeed as a powerful learning medium, is when social emotions launch unsafe feelings, when interpersonal experiences come too fast, when threat neurology fires unexpectedly, when cultural situations become unpredictable, when nations consider war, and when the complexity of day-to-day, moment-to-moment "live in" experiences become physically and psychologically overwhelming. In today's world of rapidly expanding social and technological complexity, children often enter K-12 education unprepared to handle the social learning dynamic of an average classroom. Even worse, children become victims of chronic stress when they come into schools suffering from the "less syndrome"—less safe home and social environment, less early quality learning experiences, less socially enhancing use of technology, etc. Less love and less everything else. This shuts down children's learning and greatly diminishes their innate potential. Theatre education methods are especially equipped to help such young learners deal with any degree of the "less syndrome" and with play deprivation issues.

Young theatre goers experience the complexity of the pathos "as if" it was happening for the first time through the artistry of the entertainment. Such complexity helps to provide distance. Meaning comes from the audience's ability to move rapidly between engagement in the moment and reflection about the art experience. The craft of theatre design helps this process take place, such as a 25-foot web, actors as humanized animals, imaginative costumes, stylized action, and magical and moody lighting. Watch this 90-second preview video clip used as publicity for *Charlotte's Web,* which I guest directed at First Stage Children's Theatre in Milwaukee, WI: http://firststagechildrenstheater.blogspot.com/2008/10/charlottes-web-video-sneak-peek.html (Robinette, 2008).

## Sophisticating Play

Much of my average day is spent away from formal theatre. As a professional theatre educator specializing in child drama and child psychology, I often tell people that I have the best job in the world because I get to literally play with students day in and day out for a living. As theatre educators, we spend our days sophisticating play. Our specific intent is to help students build strategies for understanding and dealing with the complexity of being human. This can involve sharing a fancy pretend meal with three-year-olds at a preschool and accidently dropping my entrée (actually a transformed Frisbee) on the floor just to see what comes next, roughhousing a second grader under my bridge in my role of the leader of the trolls when "we" don't hear a fair negotiation for coexistence, devising an original piece of theatre with fifth graders that explores the historical and contemporary violent/peaceful symbolism associated with the American Bald Eagle as part of a U.S. history unit, taking Title I seventh graders to a nursing home to collect personal stories from seniors and then performing bits and pieces the next visit as a conversation stimulating, life-validating theatre collage, and working with high school drama students to write a script on bullying to tour elementary schools (complete with teacher guide and post performance debrief strategy). Shakespeare clearly understood the power of theatre to help people of Elizabethan times unpack human complexity, and it's still popular and effective today. The Bard even uses a play within a play as a plot device. "The play is the thing," said Hamlet.

In making the case for sophisticating play as an intrinsic and powerful way of knowing, it is enjoyably contradictory to remember that one of the defining and intrinsic qualities of play is purposelessness. The intent of play is to play. It is like an artist insisting, "art is for art's sake." The concepts of telic and autotelic psychological states of mind help understanding. Someone in a telic state of mind is clear of purpose, directed toward an external intellectual background goal that is not embodied in the moment. Traditional education methods are sometimes characterized as being too telic in design. Conversely, autotelic refers to someone living in the moment—playful, spontaneous, embodied in the moment with little commitment to abstract background goals. This is what is meant by the purposelessness of play—it's autotelic learning and innate to the way we actually learn many critical things. In fact, to not play, particularly in childhood, is to risk "play deprivation," a serious condition existing most frequently in imprisoned violent offenders who seemingly have reduced empathy and limited nuanced social perspectives.

Actors, like young children at play, seek to "live in the moment," to give the illusion "as if" life is happening for the first time. Yet, theatre is an art form, action is the art object, and immediacy is the context. High intentionality evolves through this very distilled craft, leaving participants of the event rich in autotelic experience, in imaginative memory, free to replay the experience over and over in search of personal meaning. Telic repetition risks moving into boredom and limiting learning. When teaching encompasses autotelic methods, repetition brings immediacy, ritual, excitement, emotion, and longed for complexity. As stated earlier, our brain's ability to move rapidly back and forth between telic and autotelic, and at times simultaneously blending these modes of learning, is the key. A former musical theatre major of mine became the first Madame Thénardier in *Les Miserables* when it opened on Broadway. She played that role for seven years, nearly 300 performances annually, and told me she cherished every moment of it. Theatre leads with autotelic fun and engagement and integrates lasting telic understandings. Actors talk about the need to put their character's lines and actions in their body to create a meaningful performance.

Using fMRI brain scan imaging, Immordino-Yang (2011) studies social emotions and embodied brains. She suggests that we come equipped with dual empathy systems. The first empathy system focuses on external physical empathy, more closely related to the role of mirror neurons (located principally in front of the motor cortex). We grimace when we see someone fall off a ladder and break an arm or we feel excited and cheer when we see a football player return a kickoff for a touchdown. Sets of neurons fire in our brain as if we were experiencing the same actions. The second empathy system exists in the primitive subcortical brain systems that control and regulate our biological survival (circulation, respiration, heartbeat, etc.). If these systems fail, we die. These homeostatic biological platforms are recruited by our social minds, thus making our most complex social emotions literally a matter of life and death. This is an internal "as if" system used for reflection and, as mentioned earlier, for re-experiencing memories. She speaks of people in this state as manifesting a "gaze" that reveals their inward focus. Such a gaze is also critical to the acting process. If you ask someone what they had for breakfast, nearly 100% of the time you will see them briefly look away for a fraction of a second as they reconstruct this "as if" memory complete with the context in which it was experienced.

A child suffering from "less syndrome" risks biologically being short-changed and emotionally mal-wired. Literally, such a child's brain architecture may be a house of straw in that a child who grows up in an unsafe, perhaps abusive and violent prone environment, will live almost exclusively in the first empathy system, constantly on the lookout for external danger, wired with a hair-trigger to activate the fight or flight survival mechanism. A child held in a mother's arms seeks to be educated by the more experienced adult, the greater expert on living. This interdependency between social emotions and biological mechanisms requires constant updating in sophistication in order to survive living in the complexity that is our embodied social reality (Immordino-Yang, 2011).

The purpose of theatre education is to help young people build a more complex self through socially responsible practice (Lazarus, 2012). More specifically, students who learn in a theatre education context learn by "living in" endless scenes with problems to solve that enhance their understanding of complexity. High expression and embodied communication are intrinsic to the art of acting. Process drama, a theatre education teaching method based in improvisation, most often existing just for the participants and ending without a formal performance, gives voice to a child's need to experience the "mantle of the expert" (Heathcote & Bolton, 1995). Immordino-Yang (2010) suggests that this is where contemporary education falls short and where arts education must pick up the slack and infuse arts learning methods into mainstream education. It's more than enrichment; it's a critical way of knowing through embodied cognition. Playing at and in theatre exponentially increases a child's library of those "lived in" experiences that are critical to understanding the complexity of human experience.

Immordino-Yang and Damasio (2007) clearly and passionately state what social cognitive neuroscience sees as the purpose of education, a mirror to how an actor trains and to what a child learns from engaging in theatre: "From the perspective of affective and social neuroscience, the purpose of education is to increase children's abilities to recognize the complexities of situations, and to help them develop increasingly nuanced and sophisticated strategies for acting and responding."

What about cognition and academic rigor? Uri Hasson's (2011) social cognitive neuroscience research team argues:

> Cognition materializes in an interpersonal space. The emergence of complex behaviors requires the coordination of actions among individuals according to a shared set of rules. Despite the central role of other individuals in shaping one's mind, most cognitive studies focus on processes that occur within a single individual. We call for a shift from a single-brain to a multi-brain frame of reference. We argue that in many cases the neural processes in one brain are coupled to the neural processes in another brain via the transmission of a signal through the environment. Brain-to-brain coupling constrains and shapes the actions of each individual in a social network, leading to complex joint behaviors that could not have emerged in isolation.

Vygotsky got it right; we are social learners (Kozulin, 2003). Theatre exists to go into the cracks of humanity in order to better understand the complex intra- and inter-personal conflicts within, and with the moral intent to understand, heal, and consider possible solutions. Theatre education is a complex meta-cognitive process.

## Future

Immordino-Yang (2013) expresses the need for integrating neuroscientific research with ethnographic approaches.

> Now the challenge will be to develop bridges that align neurobiological measures with psychocultural ones, adapting qualitative methods for studying meaning making to a laboratory setting, or perhaps developing methods for working with participants in their daily settings before bringing them to the lab for the neurobiological phases of the study. These methods will certainly not provide the richness of ethnographic data collected by field anthropologists, but they may make a substantial contribution toward formulating a neuroscientific account of meaningful variation in the social world.

Theatre educators are, by nature, ethnographers. With our students in tow, we often choose to go into our communities to witness first hand the diverse social and cultural worlds we live in, often one character at a time. We combine ethnography and drama to create a new genre called ethnotheatre. Because we are of theatre, we are focused on human struggle and cultural unrest. Our intent is to help imagine new lives and new communities of well-being. We publish our research findings by transforming these "lived in" experiences into shared performances. Saldana (2011) believes that when we choose to write ethnodramatic play scripts and produce ethnotheatrical productions we do so because we have "determined that these art forms are the most appropriate and effective modalities for communicating observations of cultural, social, and personal life." Theatre is the art and science of how social minds learn.

Understanding complexity takes practice and rehearsal, rehearsal, rehearsal. We move theatrically from the impulse to imitate others as a child to the impulse to imitate life through art and science, through innovation and technology as an adult. Learning to think and perform like an actor and theatre artist, through sophisticated play, may well help prepare us to deal more effectively with the ever increasing moral dilemmas that make up our life drama—guns, sex, friendships, betrayal, disease, crime, violence, ecology, gender, money, government, technology, careers, family, love, and war. We are such stuff that great theatre and day-to-day living are made on. Education needs **to act.**

## An Invitation

Mary Helen Immordino-Yang (referred to above) will be the keynote presenter at the Children's Theatre Foundation of America's Annual Medallion Event in conjunction with the 2014 American Alliance for Theatre in Education's annual conference, July 30-August 3, 2014, in downtown Denver, CO. See http://www.aate.com/page/2014.

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## Chapter 11

*(IAE Newsletter #123. See http://i-a-e.org/newsletters/IAE-Newsletter-2013-123.html.)*

# Musings about Strange Attractors

**Bob Sitze**
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This chapter illustrates the intriguing possibilities that can develop when we push an analogy to the edge of its rational utility. It uses the primarily mathematical concept of "strange attractors" to demonstrate analogy-stretching.

### Understanding Strange Attractors

You are familiar with gravity and magnetism. Gravity is a force that attracts two physical objects to each other. Magnetism is a force that can attract or repel certain objects. Attractors have been studied by physicists and mathematicians. Some behave in an unpredictable, chaotic manner. Mathematicians named these "strange attractors."

In strictest scientific terms, strange attractors are mathematical constructs that help explain phenomena whose patterns seem complex or chaotic. An "attractor" is a durable theorem about the physical world that becomes "strange" because it interprets or connects ostensibly disparate events or facts. Strange attractors are scientifically useful because they can describe seemingly unconnected processes in simple terms. Defined operationally, strange attractors are intriguing because they may predict the seemingly unpredictable and invite or motivate further actions.

### My Attraction to Strange Attractors

My interest in strange attractors came almost at the moment when I first discovered that this scientific/mathematical phenomenon existed. I remember reading in *Scientific American* about Feigenbaum's Constants (http://en.wikipedia.org/wiki/Feigenbaum_constants and http://mathworld.wolfram.com/FeigenbaumConstant.html) and being awed that a decades-old mathematical formula might be helpful in understanding disparate parts of the physical world. I was also amazed that scientists were hopefully fitting these ratios to phenomena important to their research.

Over the years I began to see other strange attractors (such as those described below) that emerged as scientific/mathematical attempts to bring order to complexity. Most were mathematical, but at their roots these formulas or constructs skated right up to the edge of the meaning of "analogy." It occurred to me that "strange attractors" could be useful in more places if they were considered more broadly and perhaps less mathematically in other areas of daily life. I started playing with such questions as, "Where else in life does something 'strange' attract attention or make sense?" or "Stripped of their math, what are strange attractors really like?"

Because my professional work has always involved making sense out of social systems, I began using "strange attractors" as a way to describe new axioms in education, ecclesiology, and social change. It seemed that my audiences and readers instinctively understood how "strange attraction" described bedrock matters that were applicable across a broad spectrum of their work.

That's why I have come to see the value of "strange attraction" as a helpful way to understand and master complexities in a variety of fields of human endeavor. Thus it has not been difficult to extend this possible analogy into the field of applied neuroscience. What follows is the result of those years of happy noodling with an intriguing concept.

## An Example from Physics

To see strange attraction in action, imagine a pile of various metal filings, showing no pattern or purpose other than to collectively take up space. Now think of what happens when a strong magnet passes through that metallic collection. Some filings—iron, steel, cobalt, and nickel—are drawn to the magnet's forces, oriented toward the lines of energy the magnet has presented. In time, each of the magnet-oriented slivers can become its own mini-magnet, displaying an additional identity imparted by the magnet's presence. Those filings not drawn to the magnet's force field can be described in other ways, but "magnetized" is not one of them. What previously seemed to be an indescribable collection of metal is now explained and understood by virtue of the magnet's presence.

In this illustration, the magnet becomes the strange attractor because it enables a specific description of direction, purpose, unity, and similitude where none existed without its presence. When magnetism was first discovered, of course, it was wonderfully and oddly strange, and therefore attractive. The same thing happens in our times, when quirky bits and pieces of science emerge as newly powerful and accurate descriptors of much of what we had previously not understood that well.

## Moving Strange Attraction into Behavioral Sciences

As suggested above, the function of strange attractors has not been completely limited to math and the physical sciences. Leon Festinger's theory of cognitive dissonance burst into the fledgling science of social psychology in the 1950s (Festinger, 1957). It's the discomfort one experiences when simultaneously confronting conflicting concepts. His ideas were attacked as unprovable or vaporous. See http://www.simplypsychology.org/cognitive-dissonance.html. But as the applications of the theory started to multiply and gain traction in actionable science, the influence and connectivity of this body of knowledge began to emerge. Today, cognitive dissonance theory is a bedrock principle in the applied behavioral sciences. It has added cohesive, durable meaning, thus functioning as a strange attractor in the explanation of seemingly unpredictable behavior. For example, imagine the cognitive dissonance experienced by a terminal patient's caregiver. To provide the patient with food and medicine extends a terrible and often painful life. Conversely, to consciously deny food and medicine seems hopelessly cruel to a person one loves.

## Claiming Strange Attractors in Neuroscience

It seems defensible that several of the lodestone concepts of neuroscience may also function as strange attractors. Three familiar examples are Dunbar's Number, mirror neurons, and movement. In each case the initial discovery or theorem eventually coalesces to form a wide variety of useful applications that the original discoverer would probably not have known.

### Dunbar's Number

Expressed as the ratio between the size of the human neocortex and the size of the entire brain, Dunbar's Number (147.8, rounded up to 150) may predict the optimum number of cooperative and trusting relationships that can be sustained in human societies. Published more than 20 years ago, the original research by British anthropologist Robin Dunbar (1992) showed similar correlating ratios among other primate relational groupings.

At its onset, Dunbar's Number described:

- The average number of villagers in 21 hunter-gatherer societies around the world (150),
- The optimum number of soldiers in an effective fighting unit (under 200),
- The historic cutoff point for Hutterite communities to split into new communities (150), and
- The organizational philosophy of the GoreTex Corporation (a cap of 150 employees per manufacturing plant).

Today, debate and further application of the original research continue, harnessing its predictive usefulness to the size of online communities, shared purpose in social groupings, ideals in management theory (e.g., work team efficiency), and even the optimum size of churches. This neurobiological strange attractor could be a key to understanding as-yet-unknown elements of applied social science. Its emerging iterations may someday instruct algorithms or practices that guide the further development of social media, investment in entrepreneurial start-ups, neuromarketing (e.g., word-of-mouth approaches), monetizing of relational capital, and social psychology.

## Mirror Neurons

What began as a casual observation by Italian researchers of monkeys imitating what they saw eventually led to the discovery of mirror neurons—several varieties of cells found throughout the nervous system that assist us in the valuable skills of imitation, imagination, and self-awareness. See http://www.scholarpedia.org/article/Mirror_neurons. Today, the science surrounding mirror neurons, which includes but is not limited to motor neurons, may also have strangely attractive implications for other facets of human behavior.

This possibility is amply illustrated in the inventive conjectures and experiments that V.S. Ramachandran describes in *The Tell-Tale Brain: A Neuroscientist's Quest for What Makes Us Human* (2011). He explores how the "mirror neuron system" can explain autism, theory of mind, social systems, language development, and memory.

He suggests that mirror neurons assist our brains to determine the intentions of others, adopt their conceptual vantage points, become aware of others' point of view about ourselves, construct and use abstractions (especially metaphors), and interpret the implied actions embedded in those metaphors—perhaps the basic stuff of consciousness.

If mirror neurons are implicated in autism, as Ramachandran's experimental work suggests, many of autism's characteristics could be explained as mirror neuron system deficiencies. For example, persons in the autism spectrum have difficulty interpreting metaphors as action-prevalent expressions, connecting sensory/motor processes, understanding social cues, and acquiring and using language.

Since the 1992 discovery of mirror neurons, what initially seemed simple—the power of imitation and imagination in human brains—has found utility in fields of endeavor as diverse as sports coaching, learning/memory theory, neuro-linguistic programming, counseling, parenting, stroke recovery, research into neonatal development, addiction, prejudice, sociability, motivation, and habituation. Some of these applications may work, others may not. That's the way things develop.

While remaining mindful of Ramachandran's caution regarding "mirroritis"—mirror neurons explain everything!—we can nonetheless explore this piece of neuroscience as it continues to be useful and thus strangely attractive.

### Movement

When I'm not sitting here writing, I move around. I practice tai chi, walk regularly, steward my suburban yard, and count twig-collecting as my hobby. (For disbelieving non-twiggers: This hobby requires lots of tricky twiggy moves!) I understand the value of exercise and movement for my body. When a friend suggested that "movement" be included in my book about the applications of brain science to ecclesiology (Sitze, 2005), I welcomed the valuable addition. His basic thesis: Movement is profoundly integral to our well-being because our brains are oriented toward movement.

That thinking turned out to be prescient when John Ratey published *Spark: The Revolutionary New Science of Exercise and the Brain* (2008), a wide-ranging synthesis of research regarding brain benefits of movement/exercise. Ratey proposed that movement of any kind, and especially regular exercise, could benefit people who wanted clarity about:

- Persistent depression,
- Continuing addictions,
- Efficient and sustainable learning,
- Dementia and other memory-related matters,
- Ongoing anxiety, and
- Attention-related difficulties.

In each case, Ratey focused on the proven value of exercise to brain-related difficulties that can hamper well-being. As he gathered together extant science around the idea of movement, Ratey was able to offer people facing life-altering circumstances a basis for reasoned, actionable hope.

The phenomenon of movement/exercise now functions as a neurobiological strange attractor. Today, the precepts of movement coalesce the attention and behaviors of educators, human resources managers, occupational and physical therapists, gerontologists, psychologists, psychotherapists, and pediatricians. Due in part to Ratey's efforts, the neurobiology of movement has effected changes in entire school systems, clinical practices, regimes of rehabilitation and recovery, and the daily routines of ordinary people.

## Emerging Strange Attractors in Neurobiology

Several other elements of cognitive neuroscience may soon qualify as strange attractors. The following newer discoveries are beginning to function as durable explanations of widely divergent phenomena in our lives:

- Neurogenesis, especially in elderly brains. See http://en.wikipedia.org/wiki/Neural_stem_cells.

- Glial cells, an inevitable "system?" See http://www.wisegeek.com/what-are-glial-cells.htm#didyouknowout, and
- Polyvagal theory, including its connections to epigenetics (Sylwester & Moursund, 2013).

## And you?

You may be among those whose work in applied neurobiology generates or strengthens chunks of knowledge that affect people's lives. I hope you have found reasons to take heart, to remain strong in your resolve about the value of your work. I hope that, because you are already fitting neurobiology into life's fundamental behaviors, you will see yourself as part of a growing movement of people who can claim strange attractiveness as a part of their lifework—to understand and then to master complexity.

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The documents listed below are for this particular chapter. References from the individual chapters have been collected in the References section at the end of the book.

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## Chapter 12

*(IAE Newsletter #130. See [http://i-a-e.org/newsletters/IAE-Newsletter-2014-130.html](http://i-a-e.org/newsletters/IAE-Newsletter-2014-130.html).)*

# Knowledge Theory and Education

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Each profession is centered around a particular type of object. In medicine, it is the human body. In the legal profession, it is the law. In business, it is goods and services. In engineering, it is structures and machines.

What then is the essential object of study and practice in the education profession? In observing schools, we see that teachers' primary job is to impart the curriculum to students; students are expected to learn the curriculum; and teachers and others assess students' mastery of the curriculum.

We might conclude then that education is centered around curriculum. But if you think about it, the curriculum and the various subjects that constitute it (e.g., mathematics, social studies, English) is based on a body of knowledge. No matter what subject is being taught, the teacher is helping students acquire knowledge, apply knowledge to problems and tasks, and sometimes create their own knowledge.

So I contend that knowledge is the essential object of study and practice in the education profession. If this is true, the education profession might make greater advances if we improve our understanding of its foundation in knowledge.

In this article I want to share what I have learned so far about the nature of knowledge and its implications for education. I draw from my 40-year career in the education profession, mostly as a teacher educator, and from my study of epistemology (the philosophy of knowledge), the philosophy of science, and instructional theory.

### Knowledge as a Representation of Reality

I define knowledge in this way: Knowledge is a representation of reality. By "representation" I mean that knowledge is a kind of recording that an individual has made to encode some aspect of reality. The recording can take various forms, such as text, diagrams, photos, videos, music, spreadsheets, and formulas.

Each bit of knowledge is *a* representation of reality, not *the* representation of reality. For example, if someone wants to know the name of the state university in Eugene, they can ask me and I can give an oral answer. Or the person can read the name of the university in a hard copy of a university directory, or they can find the name at a website. Each is a different representation of the university's name.

The receptivity of knowledge to different representations is an important feature of knowledge. Here's an example. As a doctoral student in psychology, my classmates and I took a course in statistics. The professor was indecipherable to most of us. He spent most of the class putting equations on the board, talking aimlessly (in our opinion). We called the class a "magical mystery tour." The textbook, written by a distinguished professor, was no more helpful. What we did find helpful was to form study groups where we could talk our way through the equations, checking our understanding with each other. We formed our own representations of statistics (mostly oral communications) that were more comprehensible than those found in the lectures or the textbook. In fact, our representations enabled us to make sense of these other representations.

Here's another example of the receptivity of knowledge to different representations. In Eugene, Oregon, we have an ongoing film seminar, open to the public, led by a retired Hollywood film director, Tom Blank. His motto is, "You haven't seen a movie until you've talked about it." For each seminar meeting, he provides some background information about the movie, screens it, and then we discuss it for upwards of an hour. I have found that the reality of the movie often changes dramatically for me as I shift from the representations formed by the screen images to the representations formed by the discussion leader, by my fellow attendees, and by my own reflections. Often these collective representations lead us to focus on features of the film that we otherwise overlooked while watching the film or in our personal reflections.

Consider for yourself what types of representations of reality help you learn best—lectures, texts, videos, music, the Internet, discussion. Is it true that a picture is worth a thousand words? And is it possible that a video is worth a thousand photos? In my opinion, the ability to present videos is the real promise of computers for improving education. Videos, digitized for playback on a computer, can present processes, events, sounds, and objects in a manner that cannot be duplicated in efficacy by any other form of representation, other than to be an eyewitness to them. Now consider the repositories of knowledge that you use. For many centuries, libraries were the primary repositories of knowledge. The U.S. Library of Congress reflects that heritage. Now the Internet has become the greatest repository of knowledge; it can store not just a local library, but the world's libraries, in addition to images and sounds of all sorts, and anything else that can be digitized.

But what does digitization do to the representation of reality? Would you rather see a photo of van Gogh's "Starry Night" or the actual painting in the Museum of Modern Art (as I did recently)? Would you rather skype with a friend or have a face-to-face conversation? Would you rather watch a teacher deliver a live lecture or watch a digital recording of the same teacher? One benefit of watching a digitized representation of some aspect of reality is that you can do so repeatedly, each time processing more of the representation. However, being an eyewitness likely might create a more complete representation and a different emotional response. Thus, both digitization and real-life experience can serve as representations of reality, but they are not necessarily equal in terms of costs and benefits.

## The Nature of Reality and Knowledge Claims

Now let's examine the other part of my definition of knowledge. Knowledge is a representation of reality, but what exactly is reality? Philosophers have pondered this question for centuries, and there is no single agreed-upon answer to it. I like the definition provided by the Wikipedia, based on the *Oxford English Dictionary* (2010): "reality is the state of things as they actually exist, rather than as they may appear or might be imagined." This is close to my own view of reality, which is that reality is what things are like independently of our observations of them.

This definition is sensible, but it presents a dilemma. It's impossible to know what reality is like independently of our observations. Reality does not speak to us directly. A tree does not tell us that it is a tree. An atom does not tell us that it is an atom and that it has certain properties. All we can do is study these things and make representations of them. And there is no certain way to determine whether those representations are valid, because reality does not tell us that they are valid or not. In a sense, we are always peeking around the curtain of our representations, hoping that what we see beyond the curtain is reality itself.

To give you just one example, many climate scientists assert that our global climate is changing, and some politicians and business people say they are wrong. The actuality of climate, if there is such a thing, does not adjudicate in the matter. All we have to go by are representations, such as those created by scientific studies, computer models, researchers' interpretations of their findings, and policymakers' judgments about those interpretations. Each of these representations might be wrong, partially right, or remarkably correct.

The fact that we cannot know reality directly but only indirectly through our constructed representations suggests what should be a major goal of education: Teach students to embrace uncertainty. Teach them to question everything. When researchers conduct a research study, other researchers are free to question their conceptual framework, their methods, and their findings. In the arts, a work of art—a poem, a painting, an opera—does not have one correct, authoritative interpretation. Its meaning and worth are always uncertain, and can change from one period of time to another, even among professional critics. Students need to learn this type of uncertainty.

The fact that an aspect of reality can be represented in different ways does not mean that all representations have equal validity. Those who work in the professions, trades, arts, crafts, religious orders, scientific research, and other human endeavors have developed criteria for judging whether a knowledge claim is valid. If students are to acquire and use knowledge effectively, they need to view knowledge not as an absolute, but as claims that should be judged for their validity by using criteria, those developed by others and their own.

These judgments of validity are not easy. I've been an editor of several research journals, and I can tell you that, more often than not, different reviewers of a research manuscript will judge the meaning and validity of its findings quite differently. My job as an editor was to adjudicate the validity of these different representations of the manuscript. Students similarly need to learn how to adjudicate the validity of knowledge claims across the various subject areas that make up the curriculum. In public schools, however, students typically acquire chunks of knowledge without learning that it is a set of claims whose validity needs to be examined.

## Types of Reality

If knowledge is a representation of reality, is there a uniform reality or do different types of reality exist? In my view, three types of reality exist—physical reality, psychological reality, and spiritual reality. Students in public schools mostly acquire knowledge about physical reality, objects outside ourselves that our sensory organs can recognize and turn into representations.

The other two realities are internal to ourselves. One is psychological reality. For example, we can sense anger or anxiety in another, but only we can experience anger and anxiety within ourselves. Various types of psychotherapy are available to help people get in touch with these feelings and control them. Or consider the case of students who read without comprehension.

Researchers have discovered that good readers cognitively monitor their comprehension and take corrective action when comprehension fails. Educators have developed ways, such as the think-aloud method (Wilhelm, 2001), to help all students develop these internal cognitive processes.

The other internal reality is spiritual reality. When I was much younger, I took a course on world religions. That was interesting, but it's not the same thing as the study of our own spiritual reality, assuming we are in touch with such a reality. One of my classmates, Peter Pitzele (1995), represented what I mean by spiritual reality in recounting his experience in a French class. During class, he notes a fly "lying on its back, its tiny legs in the air." The fly eventually gets up and flies away, while Peter, and these are his words, having "microscopically pursued its every move, am hurtled into space, glued to its shimmering little form until it dissolves into the light. And the landscape beyond the window dissolves as well…I am traveling down a golden cone toward a center infinitely far away. I travel with the speed of light. In an instant I arrive at the center, quivering and melting. Some part of my mind is able to observe this ecstasy, and this part, gasping in astonishment, knows that I have come to God. This must be God, for here everything is answered." Peter Pitzele had encountered what I refer to as spiritual reality.

Consider the implications of this multi-dimensional view of reality for the curriculum. With the advent of the Common Core Standards, educators are placing increasing emphasis on the reading and writing skills and the STEM disciplines (science, technology, engineering, mathematics). These subjects are grounded in physical reality. Students seldom are given opportunities to explore their internal psychological reality. We do hear of efforts to train students in good health practices, such as avoidance of addictive drugs, but this training typically is expository and prescriptive rather than an exploration of one's own emotions, needs, stresses, and motivations. An exception is the incorporation of meditation in some schools as part of the school day. An example is the Quiet Time program, "a shelter and a sanctuary where students can clear their minds and ready themselves to accomplish things socially and academically" (Nobori, 2014).

Helping students acquire knowledge about their psychological reality is far from mainstream educational practice. Teaching them about spiritual reality is even farther away. Because of the separation of church and state, public schools cannot teach students to explore spiritual reality. They can teach about world religions (a subject that I took in high school), but that is not the same thing. I think, though, that public schools can and should teach students that there is such a thing as spiritual reality. They can do so by presenting the writings of individuals who had spiritual awakenings, such as what Peter Pitzele experienced. Students need not accept the validity of these representations of spiritual reality, but they should be exposed to them. Otherwise we leave a huge hole in the curriculum.

## Reality Is Infinitely Complex

Consider the complex reality of any school. If we were creating knowledge representations of it, we could focus on its current and present students. We could study each student's past, including their decision to enter that specific school, and we could study their future after they leave the school. We could study not only all current students, but all past students. Having done that, we could move on to the faculty, the staff, the budget, the grounds, and so on. You could spend an entire lifetime, and still not know everything about that one specific school.

Because reality is so complex, we are forced to specialize. Each individual is likely to become a specialist in some domain of knowledge. Specialization sometimes is put down as "knowing more and more about less and less." But that's a good thing, because reality is so complex.

Awareness of this feature of reality is important, because the school curriculum is mostly determined not by students, but by other stakeholders. Students need to learn that the delivered curriculum is just a small sliver of all the knowledge that is out there. There exists a whole other curriculum that is not taught, sometimes called the null curriculum (Flinders, Noddings, & Thornton, 1986).

I believe that educators should shrink the null curriculum by devoting some school time, especially in students' early years, to what I call exposure. By this, I mean that students should be exposed to a great many domains of knowledge and the individuals who embrace them—poets, philatelists, wood carvers, anesthesiologists, plumbers, chiropractors, CEOs, salespersons, pollsters, social workers. The list goes on and on. Preferably these domains of knowledge would be explained by individuals who have those titles rather than by just having students read descriptions of them. In this way students can discover their interests and fellow travelers. This exposure would open up the school curriculum, which traditionally has been highly circumscribed.

As an example of the need to give students time to explore, we can look to Steve Jobs, the founder of Apple, who only completed one term at Reed College. He did not like taking courses, and fortunately a dean allowed him to stay on and audit classes as he wished (Isaacson, 2011). One of them was a course on calligraphy, taught by a distinguished expert in that field. This interest in the design of script fostered Jobs' interest in aesthetics, which in turn led him to require his staff at Apple to design computers that were aesthetically pleasing and incorporated a wide variety of typefaces. The rest of the story is, as they say, history.

Because reality is so complex, the individuals who create the curriculum need to be a focus of study. As an example, I refer to a book I recently came across: *American History Revised: 200 Startling Facts That Never Made It into Textbooks* (Morris, 2010). The book is of interest to me because I once happened to teach U.S. history to eighth graders for several months. Our focus was colonial life and the Revolutionary War. I discovered from *200 Startling Facts* that the recruitment of soldiers for the Revolutionary War was terribly difficult (as it has been for other wars). The author states:

> During the American Revolution, almost as many inhabitants of the American colonies fought for the British as for the Continental Army: seven thousand loyalists versus eight thousand patriots. Furthermore, George Washington had great difficulty securing food for his troops because local farmers preferred to sell their goods to the British, who could afford to pay more for them.

Now one might argue that eighth graders should not be exposed to such knowledge or only when they are older. But the point is that some individual or group made the decision not to include representations of this aspect of colonial reality in the curriculum. My students and I as their teacher had no way of knowing who limited our exposure and why.

How did I finally become aware of this knowledge? I subscribe to a free Internet service, http://delanceyplace.com, which each day delivers excerpts from a recent book to my email inbox. The books cover many different domains of knowledge, and so I am exposed to knowledge and aspects of reality that were not part of my formal schooling. This exposure supplements my occasional reading of *The New York Times* list of best-sellers, my weekly reading of *The New Yorker,* whose articles cover a wide range of topics, and occasional forays into bookstores where I wander about. As educators, we need to ask whether the students who graduate from our schools have developed their own methods of constantly exposing themselves to new aspects of reality or whether they are content to transverse only within well-worn tracks.

## Knowledge Is Embedded in Communities of Practice

The concept of a community of practice was developed and popularized by two researchers, Jean Lave and Etienne Wenger (1991). A community of practice, broadly defined, is a group of individuals who form an organized group to create or use knowledge for particular purposes. Indeed, much if not all human knowledge is linked to a community of practice that created and uses it. Lave and Wenger make the point this way:

> The community of practice of midwifery or tailoring involves much more than the technical knowledgeable skill involved in delivering babies or producing clothes. A community of practice is a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice. A community of practice is an intrinsic condition for the existence of knowledge….

One of the most interesting things about knowledge is that it can be used differently by different communities of practice. Consider mathematics. In my case, I studied algebra, geometry, trigonometry, and calculus in high school and statistics at the University of California at Berkeley. My main professional use of math has been statistical analysis of psychological research data.

Now my father was a machinist and tool and die maker with an eighth-grade education. He studied math, too, and used it daily in his job, but it was a different sort of math. It mostly involved measurement to get objects lathed to a certain level of tolerance, or in other words, within an allowable level of measurement error. So, both of us used math, but different kinds of math, for different purposes and within different communities of practice.

Lave and Wenger point to apprenticeships as a worthwhile and historically common way to incorporate new members into a community of practice. For example, they make this observation: "In the United States today much learning occurs in the form of some sort of apprenticeship, especially wherever high levels of knowledge and skill are in demand (e.g., medicine, law, the academy, professional sports, and the arts)."

One of the great shortcomings of public education is that it most often conveys knowledge devoid of any community of practice. Many students have no idea how math, social studies, physics, and other subjects fit into their present and future life. Education would improve greatly if teachers helped students make connections between knowledge and the students' own current communities of practice, such as their sports and entertainment activities, and in the communities of practice that they might someday enter. Apprenticeships, or what I consider its near equivalent internships, would make these connections even stronger. With the current emphasis on having students develop higher cognitive skills, the idea of apprenticeships becomes even more appealing.

The incorporation of communities of practice into the school curriculum is complicated by the fact that different students will be attracted to different communities of practice. So, for example, should schools impart knowledge that is useful for college-bound students and different knowledge for students who wish to go into the trades, and still different knowledge for students who wish to become artists or to pursue a spiritual path? The current vision is that all or most students will be college-bound. This vision ignores the highly diverse nature of student interests and talents.

## Types of Knowledge

Representations of reality, such as an essay or painting, do not speak on their own. As we examine them, we interpret them to produce meaningful knowledge. So, for example, when I look at a painting, I know that it is a painting because I have learned the concept of a painting. If I can recognize trees, sheep, and a river in the painting, it is because I have learned these concepts. If I can determine the ratio of the painting's height to its length, it is because I have learned rules for computing a ratio.

We see, then, that our ability to form concepts and rules is critical to the development and use of knowledge. I think of concepts and rules, together with facts, as a typology of knowledge types. One prominent typology (Gagné, Wager, Golas, & Keller, 2005) includes five knowledge types that are called *categories of learning outcomes*: intellectual skills, cognitive strategies, verbal information, motor skills, and attitudes.

In my typology, a fact is a representation of one thing that has no generalization. The name of the institution where I spent most of my career is the University of Oregon. That's a fact. It tells you the name of my school, but of no other school. The University of Oregon is located in Eugene, Oregon. That's a fact, because it tells you where this university is located, but not the location of any other university.

Concepts are generalizable. A concept is a knowledge representation that groups things on the basis of shared characteristics. For example, marriage is a concept. You can group people according to whether they are married or not. Divorce is another concept. You can group people according to whether they are married or were married but no longer are.

Rules are relationships between concepts. Mathematical formulas such as $E = mc^2$ are rules. That formula expresses a relationship among three concepts—mass, energy, and light. Golf, which I play, has a huge number of rules, all of them questionable. Grip the club in a certain way, take it away into a backswing in a certain way, and create a downswing in a certain way. And follow those rules consistently, which should lead (in theory at least) to a repeatable golf swing.

Facts, concepts, and rules can vary in importance, significance, and value, depending on the individual or group. February 18 has some significance to me, because that is my birth date. House is a concept, so all things called a house have certain things in common; however, houses vary in monetary value. A discovery about the speed of neutrinos is important to atomic physicists and to those with a general interest in science, but probably of no importance, meaning, or significance to the general public. Crime is a concept to which we attribute negative value.

The fact that humans have created different types of knowledge to represent and interpret reality has important consequences for curriculum. To illustrate, I will draw again on my experience teaching the American Revolutionary War to eighth-graders. The American Revolutionary War constitutes a set of facts, but "revolutionary war" is a concept. So should I teach this topic as a set of facts about the war (mostly about nations, battles, generals, towns, and dates) or should I teach the concept of a revolutionary war and its related concepts, revolution and revolt?

It happens that the Soviet Union was undergoing a revolution (1989-1991) that led to its dissolution while I was teaching my course. I decided to tape segments of the PBS MacNeil/Lehrer news hour reporting this revolution and show them to the class. The students were quite interested in watching these segments, because they knew that something important in the world was happening, but weren't sure what it was. I also asked students to bring something to class having to do with revolution or war. One student brought in his dad's military dog tag; I brought in a CD of the Beatles' song *Revolution* and played it for the class. In this way, students learned not only about the American Revolutionary War, but also about the concept of revolution and the various reasons why people organize a revolt. As a result of my focus on concepts and not just facts, the students probably were in a better position to study any other revolt or war throughout recorded history.

This example suggests that it requires significantly more effort to design instruction for the teaching of concepts than for the teaching of facts. One needs to search for the examples, preferably in different media, whereas facts are inherently simple and can reside comfortably in textbooks or on the Web. The teaching of rules is complex, too, especially if the teacher wants to show how the rules were developed and their application across many different situations. Thus, I would argue that the design of instruction for teaching concepts and rules is beyond the capacity of the individual teacher. If this is true, we need to rethink how instruction should be designed and delivered to students.

## Knowledge Creation, Acquisition, and Use

Knowledge can be thought of as having three stages. First, someone has to create knowledge. Then others can acquire that knowledge. Finally, those who have acquired this knowledge can apply it. My analysis might seem simplistic, but I find it helpful in thinking about knowledge as the foundation of education.

Researchers are in the business of creating new knowledge, hopefully, knowledge that has wide application. Others create local knowledge, for example, a shop owner who develops and maintains an inventory, perhaps using a computer application, of the store's goods. (The inventory is knowledge, because it represents the store's goods.)

I think that students should have many opportunities to create knowledge. This might be in the form of doing projects, such as gathering information about a particular topic and organizing it into a report. The most useful activity, though, would involve creating knowledge within a community of practice. To illustrate, permit me to share a personal example. In all of my education, which included parochial school, a prep school in New England, and an Ivy League college, the most valuable learning occurred in my doctoral program in psychology at the University of California at Berkeley. We were required to do research projects from the beginning of our program and were assigned a professor to guide us. I did not have a clue about how to start such a project (my college major was English), so my advisor recommended that I start reading articles that reported psychological research. Gradually I figured out the steps of a research project, found a problem that interested me (whether incubation facilitates creativity), collected data, and wrote up the results in two papers that were published in refereed journals. All this with just a course on statistics and a good advisor. I never did take a course on research methodology, although I have co-authored two textbooks on this subject.

Rather than being stimulated to create knowledge, students generally are engaged in the task of acquiring knowledge that others have created. The instruction is bound within the artificial constraints of a classroom, with the teacher lecturing, assigning homework, and testing how much knowledge each student has acquired. Perhaps this emphasis on knowledge acquisition is what leads many students to be bored by their school subjects and eventually drop out of school.

In the third stage, the learner has the opportunity to apply knowledge. In early grades, students learn decoding and then apply this knowledge to reading text. In later grades, they will be asked to write an essay that requires them to apply knowledge they have acquired. At many grade levels they will be asked to solve mathematical or scientific problems of the sort that one commonly sees in textbooks and college admission tests. My criticism of these school activities is that they are often artificial. As an example, this type of math problem comes to mind: When will two trains traveling different rates of speed from opposite locations pass each other on a set of parallel tracks? Who really cares to know?

Once again, the concept of a community of practice is relevant. Opportunities to apply knowledge are valuable, but much more so if learners are applying knowledge that interests them to problems of practice that also interest them. To illustrate, consider the fact that many companies have developed a specialization called knowledge management (Frappaolo, 2006). For knowledge managers, the purpose of knowledge creation and acquisition is to use it to improve an organization's ability to innovate and respond to market conditions.

Peter Drucker, the noted management theorist, argues that knowledge, not labor or raw material or capital, has become our most important economic resource (Drucker, 1994). But it is not knowledge itself, but rather the application of knowledge that is key. For example, Drucker states that the comparative advantage of one country over another in the world economy is this:

> The comparative advantage that now counts is in the application of knowledge—for example, in Japan's total quality management, learn manufacturing processes, just-in-time delivery, and price-based costing, or in the customer service offered by medium-sized German or Swiss engineering companies.

## Final Thoughts

I have tried to make the case that knowledge is the fundamental object of study and practice for the education profession. Philosophers, instruction design specialists, and others have developed a set of concepts that provide the basis for a theory of knowledge, or what I call knowledge theory. The primary concepts that comprise knowledge theory are: representations; types of reality; reality complexity; knowledge claims and validity; types of knowledge; communities of practice; knowledge creation, acquisition, and application.

The brief sketch of knowledge theory that I present here calls into question the soundness of many current schooling practices—the lack of curriculum diversity, the selective nature of the curriculum, instruction devoid of a community of practice, an almost exclusive reliance on classroom instruction over real-world experience, and the prevalence of sterile representations of reality in textbooks. In addition to serving as a critique of current practices, knowledge theory can also point the way to new practices that enhance learners' personal lives and participation in society and the workplace.

Some people think that the Common Core Standards and the increasing use of technology (e.g., providing students with iPads) will elevate public education to a new level. However, I see two major problems with this vision. One is that education is still pre-scientific, certainly when compared to professions such as medicine and engineering. It relies on tradition rather than on theory and research.

The other major problem is that public education is highly fragmented because of the commonly held belief in local control of schools. Local communities and individual teachers lack the resources required to develop high-quality curriculum materials based on a careful analysis of knowledge that diverse learners at different developmental levels need. For example, no community or state would think of developing its own cars or films for theatrical release. The costs would be too great and the talent pool is too small. Yet schools and individual teachers continue to rely heavily on their own limited resources to create and implement instruction. Even teachers who design good instruction eventually retire and take with them whatever craft knowledge they have acquired.

The alternative is to gather a great pool of diverse talent experts and give them the resources to develop representations of reality, using multiple media but especially video; make these representations easily accessible for diverse settings and students (most likely using computers and the Internet); and then disseminate them, with training in their use, to teachers and to students who are capable of learning independently.

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## Part 3

# The Complexities that Groups Face

Organizations and institutions must also understand and master the complexities that define their mission. The three chapters in Part 3 illustratively focus on the Education profession, describing how it began to explore the basic neurobiological underpinnings of its complex societal assignment. It then gradually moved towards an understanding of, and then mastery of, the roles that the cognitive neurosciences will play in defining educational policy and practice.

## Chapter 13

*(IAE Newsletter #120. See http://i-a-e.org/newsletters/IAE-Newsletter-2013-120.html.)*

# Understanding Our Brain and Applying that Knowledge

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## Background

The 1910 Flexner Report (http://en.wikipedia.org/wiki/Flexner_Report) decried 19th century medical research and training. It eventually led to advances that moved medicine from its behavioral orientation in which doctors with a limited understanding of body systems prescribed nostrums to patients who had described their symptoms. To be fair however, what options did doctors have, given the limited biological understanding at the time?

During the 20th century, medicine dug deeper inside our body in search of the underlying causes of invasions (such as infectious disease) and insurrections (such as cancer or asthma). During the 20th century the percentage of deaths that occurred during childhood dropped from 30% to 1%, and life expectancy expanded 30 years. Infectious diseases are now reasonably well understood and controlled, and such body insurrections as cancer are rapidly moving towards effective understanding and control. Understanding the biology of our body made the difference.

Educational policy and practice had a similar limited perspective when I began my teaching career in 1949. Behaviorism, the reigning psychological belief, considered our brain to be a "Black Box." Educators could observe incoming stimuli and outgoing behavior, but Behaviorists believed that the intervening cognitive activity was too complex for discovery. Instead, they focused on stimulus and response.

An initially small number of educators begged to disagree, and that number increased over the years as the brain sciences made startling discoveries that often made intuitive sense to fascinated teachers. Much about cognition still awaited discovery, but teachers who work with students for years functionally understand much of what's going on within student brains, even if they didn't understand the underlying biology.

Educators made errors along the way as they sought practical applications of these cognitive neuroscience findings, but most of the fallacious applications disappeared over time. A new field of Educational Neuroscience emerged to displace Behaviorism. It has become a respected scholarly search for legitimate educational applications. How we got to the current point of understanding our brain and its cognitive processes is an interesting story.

## Beginnings

Primitive humans didn't understand the purpose of our brain and how cognition was processed. Four thousand years ago, however, some Egyptians, Greeks, and perhaps others had already begun to think of a brain as the body's center of decision and action. However, conventional wisdom still opted for the heart to at least process emotion. Although we now know much more, we're still mystified about several central brain and cognition issues, such as the neurobiology of consciousness and morality (Sylwester & Moursund, 2013) and how neuronal networks can develop and maintain memories of past events. We can only speculate about the future, and what roles sleeping and dreaming play in life.

It became increasingly evident over time that our brain's neuronal and hormonal systems determine and direct cognitive decisions, but it wasn't until the late 20th century that the research momentum towards a reasonably clear understanding of brain and cognition began to develop. Our brain's awesome complexity was its own barrier to understanding itself. At the cellular level, our brain's three-pint three-pound mass is somewhat evenly divided between perhaps 100 billion minuscule neurons and a trillion much smaller glial support cells. Neurons are massively interconnected—most to multiple neurons within millimeters, but others to a muscle as far as a meter away. Any neuron is only a few neurons away from any other neuron. If that surprises you, realize that the coding system of the world's five billion phones can quickly connect any two of them via a sequence of 7-12 digits. Or, consider the "six degrees of separation" idea that a chain of a friend of a friend of a friend…(a chain of six friends) links you to almost anyone in the world. See https://en.wikipedia.org/wiki/Six_degrees_of_separation.

Written documents and artifacts from early humans allow us to speculate about what might have happened as human frontal lobes developed sufficiently for self-awareness and thoughts about the nature of existence. Expanded frontal lobes had earlier led to tool-making capabilities with sticks and rocks, and later to include various fabrications. The domestication of animals and plants along with cooperative human relationships allowed individuals to expand their personal support capabilities. Frontal lobe expansion also led to increased curiosity about frequently unseen forces, such as seasonal and weather changes and the causes of illness, birth, and death. Science eventually emerged to help explain these phenomena.

If understanding seemed too complicated to early humans, perhaps spiritual deities could provide a useful solution. Deities could control what's good and bad in the world, but they would allow individual autonomy about what seems personally appropriate and inappropriate. The concept of deities removed the need to immediately know how our brain determines and executes decisions. The observation of behavior and the concept of a disembodied analogical *mind* would be sufficient, at least for now. Another widely held position that robustly continues throughout the world is that early humans didn't create deities, but rather that deities created humans and the rest of the universe.

## Microscopes and Animals

Biologists first used microscopes in the mid-1600s to optically enlarge the size of miniscule cells. Electron microscopes that significantly enhanced cellular resolution emerged in the 1930s. See http://inventors.about.com/od/mstartinventions/a/microscope_2.htm. The discovery of dyes that selectively stain cells and cell components allows scientists to visualize only what they want to observe. Brain scientists use dyes to better understand interneuronal connectivity.

Ethical constraints limited research on human brains. Animals such as mice provided a useful substitute (although some also consider that to be unethical). Scientists also compared the autopsied brains of deceased normal people with those who had various cognitive and motor impairments. Animal and cadaver research was difficult and principally inferential, and so scientists needed to go one step further into direct observation and coding mechanisms.

## Genetics and Brain Scans

The 1953 discovery of DNA sparked an unprecedented advance in genetics. It provided the simple coding system that regulates how our body's (approximately) 23,000 genes produce the protein scaffolding and machinery of our body's cells, and this development determines much of our understanding of our physical and cognitive self. See http://news.discovery.com/human/genetics/human-gene-count.htm. Cellular connections and interactions are central to all body systems, and especially so within our brain.

Neuronal network systems, however, still seemed complex beyond comprehension, but that is now changing. The recent development of at least eight kinds of brain imaging technologies that measure and display variations in chemical composition, blood flow patterns, and electromagnetic fields opened up the possibility of studying brain organization and function in ways that were not previously thought possible. See http://en.wikipedia.org/wiki/Neuroimaging.

Mathematicians have also entered the study of brain processing. They're searching for mathematical formulas that explain our brain's *edge of chaos* operation that allows it to quickly shift backward and forward in determining which of dozens of simultaneous events bombarding our sensory and thought processes will achieve attentional dominance, shifting us towards decision and action. See http://theedgeofchaos.org/about.

Educationally-oriented studies related to perception, thought, and action now typically use Functional Magnetic Resonance Imaging (fMRI) machines in university research centers. fMRI permits scientists to identify specific regional activity that occurs when the subject is carrying out a task, such as identifying a picture or reading a text. Researchers can then, for example, compare regional differences between two subjects who differ in reading effectiveness.

The Allen Institute for Brain Science (http://www.alleninstitute.org) decided to return to the less complicated brain of a mouse in order to get a complete picture of a brain. They have now produced a complete imaged atlas of a mouse's brain. Can an equivalent atlas of a human brain be far behind?

When we realize what we've learned about the neurobiology of our brain during my professional career and add the career of a graduate who will now begin a similar career trajectory, one can only think that the past is but prologue. An expanded understanding of the wet brain inside our skull and increased technological advances in the dry computerized brain on the outside will combine to redefine educational policy and practice in ways that I can't even begin to imagine. The Resources section below provides information on relevant organizations, websites, and conferences that combine brain research and educational policy and practice.

## Resources

International Mind Brain Education Society. See http://www.imbes.org.

Neuroscience Education website. See http://faculty.washington.edu/chudler/ehceduc.html.

Sharp Brains. *Brain fitness and cognitive health.* See http://www.sharpbrains.com.

The Dana Foundation. See https://www.dana.org.

A number of conferences focus on issues that combine cognitive neuroscience and education. They include presentations by both scientists and educators. Examples include:

- Learning and the Brain Conferences. See http://www.learningandthebrain.com.

- Jensen Learning. See http://www.jlcbrain.com.
- Mind Matters. See http://patwolfe.com.

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## Chapter 14

*(IAE Newsletter #126. See http://i-a-e.org/newsletters/IAE-Newsletter-2013-126.html.)*

# Embracing the Complexity of Mind, Brain, and Education

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On a recent journey to attend the annual conference of the Alternative Educators Resource Organization (AERO) in New York, I found myself completely lost on a small stretch of road in Elizabeth, NJ, where travelers rapidly confront eight separate highways that come together to cross bridges towards Manhattan or neighboring boroughs. I accidently exited at one of the convoluted ramps that lead me onto a dizzying journey through endless U-turns and jug-handles. I did finally arrive safely at my destination, and after enjoying a thoroughly engaging conference, I found myself coming back again and again to this agonizing moment in my travel history. The experience then seemed to me the perfect metaphor for issues directly facing us in education. As we try to apply the growing knowledge from the neurosciences to classroom practice, the challenges of merging our paths across disparate fields has created a convoluted mish-mosh of brain-based-neuro-edu-myths that have caused considerable confusion in educational practice.

Before becoming an educator, I had previously worked as a research neuroscientist focused on system-level neuroscience. This experience showed me that isolating individual cells, neurotransmitters, and brain nuclei was meaningful only when viewed within the functioning of our entire nervous system and behavior. When I subsequently moved into educational leadership, I similarly looked at the issues of organizational dynamics. Could the frameworks of complexity theory help educational leaders to understand the emerging transdisciplinary field of Mind, Brain, and Education (MBE)?

Transitioning from neuroscience into education as a graduate student led me to the dissertation challenge of merging the two complex disciplines. I thus focused my research on how neuroscience discoveries can inform educators on how best to enhance instruction. My dissertation utilized a grounded theory research design in which I interviewed a panel of educators who also had backgrounds in the fields of neuroscience. My dissertation findings suggested that the merging of the two fields should not occur under the dominance of an individual field, but rather through a dynamic system of interactions between the multiple fields (Larrison, 2013). This is where the field of MBE comes in. MBE itself is not a field of research, but it represents that place where all fields of scientific knowledge can merge to help create a new form of pedagogical practice. Autonomous agency, emergence, and co-evolution are three principles from complexity theory that I believe can assist educators as they work towards understanding this new transdisciplinary effort.

## The Principle of Autonomous Agency

As I was trying to understand where this new field of MBE existed in the realm of education, I came across a number of conflicting explanations. In my own naiveté, I had assumed that MBE was the main source of the effort to combine knowledge from neuroscience, psychology, and education. There was a popularized view that MBE and educational neuroscience were one-and-the-same. In an extended entry, Wikipedia (2013) suggests rather that:

> Educational Neuroscience (also called Mind Brain and Education or Neuroeducation) is an emerging scientific field that brings together researchers in cognitive neuroscience, developmental cognitive neuroscience, educational psychology, educational technology, education theory, and other related disciplines to explore the interactions between biological processes and education.

I was conflicted with this view. The problem was that, when creating something new, what happens to the old? The work of educational neuroscience, or more importantly the science and psychology of learning, is not new. What happens when neuroscience labs move into the classroom in order to be grounded in real life learning situations? According to complexity theory this type of merging of fields is not necessary, and in fact such an approach diminishes both fields.

Autonomous agency was first used in understanding artificial intelligence and in computer programming to describe how small independent programs or agents would contribute to a well-functioning whole. Looking to this definition, it became clear to me that by allowing each field to maintain autonomy we retain a greater depth of expertise. I came to believe that this is how we should approach the new field of MBE.

Once I had reconciled the idea that the field of MBE was made up of separate autonomous agents, I was still left with the same problem of finding the common ground. How does one create a place where all these ideas can come together, not in a chaotic mess, but in an elegant meaningful manner? It was a problem expressed over and over in my conversations with educational leaders, and the problem seemed considerable. Differences in methodologies, vocabulary, and general goals created such a vast divide. Several of the educators in my study suggested that only tenuous connections were possible at this point. Personally, as one who had moved from neuroscience into education with the goal of seeing change in classroom practice, I was not willing to wait. I knew of a wealth of knowledge that could be applied to practice, and moreover that there existed a great desire of teachers at all grade levels to see this happen.

I began to see the solution to this problem of merging of fields through the application of a second principle of complexity, emergence.

## The Principle of Emergence

It was following a discussion with the current president of the Brain, and Neuroscience Special Interest Group at the annual American Educational Research Association (AERA) convention that I fully embraced the concept of MBE as what she described as "a translational science," something that truly lives within the intermediary space. What does it mean for a field to exist outside the existing structures? I felt a great deal of excitement at the idea of working in a domain whose boundaries are being defined and redefined through the shared communications of multiple stakeholders. I was beginning to get a sense of what such a field would look like, a super-highway of emerging concepts that would be tested and re-applied to the construction of a continually moving dynamic system.

I have always been interested in emergent approaches. Before entering the Center for Molecular and Behavioral Neuroscience (CMBN) at Rutgers University, I was part of the Institute of Animal Behavior, a program grounded in ethology (scientific and objective study of animal behavior)–an approach popular in the 1960s that was based on pure observation. I believed that this methodology could help to revive a more complex approach to behavioral neuroscience. When I moved into teaching, I struggled with providing lesson plans, since much of what I brought to the classroom came from an emergent approach guided by student interest and abilities. (Parenthetically, I think we have lost much of the art of teaching by the use of pre-scripted, outcome-oriented curriculum).

For my dissertation, I was drawn to a grounded theory approach, allowing significant codes and themes to emerge from a more open conversation with a set of incredible leaders in the field. When thinking about the principle of emergence, I could see that as a conceptual framework—a phenomenon that is being embraced in a number of areas in the sciences today—and I wondered, "Is the natural progression as things become more complex to move away from pre-formed structures towards processes of emergence?"

I love the idea that an emergent field can hold the space between. For MBE, that space is where the theory meets pedagogical action. As various parent disciplines advance and expand into their neighboring fields, I see the need for a unifying force—one perhaps like an attractor—that can represent the shared goal and direct activity towards it. By focusing on emergent properties, it is possible to see how none of the original fields will be reduced or diminished. Those ideas, crystallized in the minds of leaders in different fields, will rather serve as guides for the creation of more deeply nuanced perspectives. It will allow for a deeply complex perspective unattainable in any of the individual fields alone, and yet not possible without allowing for each field to develop independently.

## The Principle of Co-evolution

Co-evolution is a central component of complexity theory that can be used to understand how the autonomous agents of separate fields can contribute to a more profound system of education based on the neurosciences. In interviewing educators for my dissertation, almost everyone agreed that there was incredible growth occurring in transdisciplinary work at the crossroads of education and neuroscience. One described it as the "sea level rising" and "all of the boats along with it." This exponential expansion of the knowledge base in all of the sciences is due to our advances in technology and to our ability to share this knowledge through instantaneous online access. It is clear that information sharing is able to deepen our understanding across fields of research and practice that were previously isolated.

However, in my conversations with educators, there was some fear that the real value of this information would be lost unless meaningful shared dialogues could be created. This is the real work of MBE, to create active connections among the different autonomous agents in order to help find shared meaning and vision. The creation of shared avenues of conversation represents a means of enhancing co-evolution, and decreasing the lag time between developments in the sciences, and practical application of those developments in education.

While writing my dissertation, I looked for models and metaphors to help understand the processes at work. Perhaps what MBE is able to provide is the super-highway of information across fields, creating a structural framework and force for effective action and interaction across the fields of neuroscience, psychology, and education. The analogy of MBE representing a place for dynamic interaction (space between) rather than a static location (independent field) is one that can help to permit all players to contribute to this important effort of informing education through the brain and learning sciences.

As we move into a great awakening of the capacities of learning and how to best teach, it would be a shame if we were to apply rigid approaches misaligned with our growing understanding of neurodevelopment. MBE shines a light out of the morass of scripted curriculum and multiple-choice tests and points us towards process-oriented, student-directed activities sure to create a generation of critical thinkers and leaders prepared to find thoughtful solutions to as yet unknown problems.

The International Mind, Brain and Education Society is an organization that seeks to facilitate effective, cross-cultural collaboration in biology, education and the cognitive and developmental sciences. See http://www.imbes.org.

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**Chapter 15**

*(IAE Newsletter #127. See http://i-a-e.org/newsletters/IAE-Newsletter-2013-127.html.)*

# The Five New Cognitive Complexities that Teachers Confront

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## Introduction

Many dismiss teaching as a simple job. American adults often think they know what it takes to teach because they observed teachers for at least 13 years. Even many of those who became teachers may rely more on their student recollections than on professional training as the primary basis of how to teach—in effect quickly skimming and/or ignoring their program's advice on how to incorporate cognitive neuroscience and computer technology into classroom instruction.

During the past 50 years teaching has profoundly moved its focus from a disembodied mind to a biological brain, and from paper to powerful portable computers. This escalation increased tremendously over this past decade. Our own work in teacher education and staff development during this period suggests that education should institute a systems perspective on how best to solve the instructional complexities that teachers daily confront. Teachers must still enhance learning within a diverse set of students, realizing that all students have individual capabilities and challenges and the potential to learn.

We've focused on two emerging issues that we'll explore below: (1) what advances from mind, brain, and education will potentially enhance student learning in our increasingly complex society, and (2) how we can make these advances engaging and practically useful to educators.

## Shifting the Focus of Education

It's becoming increasingly clear that education needs to shift from the simple transmission of facts toward cultivating minds that can recognize and creatively solve novel problems, communicate and work effectively with many others, and embrace self-directed, continual learning throughout one‘s lifetime. A report from the National Research Council on "Education for Life and Work" (Pellegrino & Hilton, 2012) identified three domains of 21$^{st}$ century competencies that require explicit instruction: cognitive (thinking and reasoning), intrapersonal (regulating one's behaviors and emotions to achieve goals), and interpersonal (relating to others and understanding others' points of view).

Teachers must direct the instructional transition from a narrow emphasis on lesson content to incorporating the concomitant goal of guiding students to "learn how to learn." They will need the support of administrators and policy makers at the local and state level to expand their mission to equip all students with the knowledge and skills they will need to thrive in college, the workplace, and a global society. Theory and research from educational neuroscience and the field of mind, brain, and education fortunately identify effective strategies for such teaching and learning. These strategies also address the professional complexities of teaching by engaging preconceptions, developing a conceptual framework, and engaging in metacognitive thinking (Bransford, Brown, & Cocking, 2000).

We worked with the Florida Department of Education in the late 1990s to lead a series of workshops for teachers who then conducted action research in their classrooms to deepen their understanding of the possible applications of educational neuroscience discoveries and then to share what they had learned with colleagues. Three years of working and modeling with those teachers led to the development of graduate degree programs with a major in Brain-Based Teaching with the Abraham S. Fischler School of Education at Nova Southeastern University. The programs retained the action research component to better facilitate integration of the material studied and to underscore the need for teachers to manage the complicated work of guiding students to achieve more of their learning potential. It also added to the school district's knowledge base of effective teaching practice.

## Toward a Conceptual Framework of Teaching and Learning

New findings that have great potential significance to educators arise regularly, and many educators are intrigued by what these discoveries might mean for teaching and learning in their classrooms. In the last few years, to name just two examples, the neuronal underpinnings for metacognition have been identified, and new studies support the malleability of working memory (Fleming, Huijgen, & Dolan, 2012; Klingberg, 2011). How can we as educators analyze and identify the potential for acting on this exciting research? Establishing a conceptual framework of core concepts that are at the foundation of this approach of “cultivating minds” can help educators more clearly identify how emerging findings might fit into the toolkit of their professional practice.

In *Five Big Ideas for Effective Teaching,* we explore major cognitive discoveries as the building blocks of such a framework (Wilson & Conyers, 2013). A brief synthesis of the research follows:

1. Neurocognitive plasticity: How can we best keep the concept of neuroplasticity front of mind at all levels for students, teachers, administrators, and parents? The dominant, but often unacknowledged, paradigm has been that the brain is fixed, that each of us is born with a predetermined cache of intellectual capacity. Setting aside this misconception can be immensely motivating for teachers as they embrace their capabilities to keep learning and growing throughout their careers and beyond. Further, student achievement is also predicated on the recognition that virtually all students can become “functionally smarter” when supported with both effective instruction and their willingness to undertake the sometimes difficult work required to advance academically. Understanding the concept of neuroplasticity can empower students to take charge of their learning and to more accurately attribute the causes of their successes and setbacks. It can also positively support a change in expectations about student learning potential.
2. Potential: How can we eliminate the divide between mission statements celebrating the potential of all students to succeed and the more deeply held assumptions that belie those sentiments? These assumptions arise, for example, in the practice of reserving instruction on higher order literacy and thinking skills for students identified as gifted while focusing on basic skills training for others. When children begin school without the reading readiness

skills that their peers possess, those assumptions may lead teachers away from a focus on the intensive instruction and exposure to reading that these children need to succeed. It may also lead toward an often-unspoken belief that such students lack the cognitive potential to read on grade level with high comprehension. As a result, while almost all students have the potential to read on grade level by the end of first grade, 30% do not do so (Allington, 2011). Presenting an evidence-based case for the learning potential of all students can help eliminate this downward spiral of low expectations.

3. Understanding intelligence: How do we move away from the view of intelligence as a single fixed entity, with IQ scores as the prime predictor of life success? This concept has a powerful gravitational pull, representing a tremendous opportunity cost that defies reality. In fact, cognitive tests predict only about 6% of the variance in job performance (Pellegrino & Hilton, 2012). Other malleable attributes, such as an interest in developing creative abilities, or a willingness to persist have significant impact on the trajectory of our lives. Furthermore, directing education narrowly on the cognitive skills measured in IQ tests misses out on opportunities to guide students to discover other cognitive styles that may be more suitable for them and to develop other forms of intelligence, such as their creative and practical capabilities. We need to widen our views of intelligence in a way that weaves in other big ideas from this framework to support a dynamic view of learning across the life span.
4. Body-brain system: How do we bring our acceptance on the need for an active mind and a healthy body into a single focus on learning? Healthy nutrition, regular physical activity, and positive relationships are not “frills,” but key aspects of academic achievement. A variety of studies show that regular physical education supports school performance, and a growing body of research connects exercise and proper nutrition to enhanced frontal lobe function, attention, and recall (Ratey, 2008; Sibley & Etnier, 2003; Tomporowski, Davis, Miller, & Naglieri, 2008). In addition, a positive learning environment in which students feel safe, secure, accepted, and encouraged to take intellectual risks enhances their motivation and participation in learning.
5. Metacognition: How can we encourage explicit instruction on the use of cognitive and metacognitive strategies to improve students’ learning across all subject areas? A wide body of educational research supports the positive impact of teaching students to think about their thinking with the aim of improving learning, and yet instruction on metacognition is nowhere near commonplace. If educators are empowered to incorporate lessons about the power of “driving their brains” from the early grades on, students will be better equipped with the cognitive, interpersonal, and intrapersonal skills they will need to thrive in school, in their personal lives, and in the working world.

Imagine an education system that systematically employs a conceptual framework such as the foundations described here in developing instruction, formative assessments, and curriculum. How many more children and youth would discover the thrill of success through their own hard work and self-directed learning? How many more people would be attracted to a profession where their expertise and contributions are acknowledged and celebrated? Imagine how many people would enjoy greater well-being if they had the opportunity to master the skills of driving their brains and managing their body-brain systems more effectively. Picture a world in which young people enter the workplace and pursue their dreams as curious, competent, creative thinkers and problem solvers who can collaborate to improve the world. That is a vision worth striving for—in all its glorious complexity.

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## Part 4

# Late Life Complexities

Life is finite. We spend a lifetime understanding and then mastering the various complexities in our life. If we arrive at death through a gradual decline, our body/brain systems will often shut down in the reverse order in which they developed early in life. Hopefully, a life well-lived

**Chapter 16**

*(IAE Newsletter #131. See [http://i-a-e.org/newsletters/IAE-Newsletter-2014-131.html](http://i-a-e.org/newsletters/IAE-Newsletter-2014-131.html).)*

# The Reverse–Late Life Decline

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Our exploration of understanding and mastering complexity began with the story of Zed, an eight-year-old boy who had asked his father to explain a televised NFL game. Zed then sat by his father during the rest of the season and learned about football. By the end of the season, patient parental mentoring had helped Zed develop an excellent beginning understanding of the procedures and complexities of the game. When this year's football season began, Zed joined in a weekly game prediction activity with a half dozen adults in his extended family. Zed's predictions won during all of the first five weeks of the season.

Infants are born with limited intellectual and motor capability. The basic sensory/motor control and cultural knowledge that children master during their first decade is remarkable, as is their adolescent move from a dependent childhood towards autonomous adulthood. Childhood is about learning how to be a human being and adolescence is about learning how to become a productive reproductive human being.

Human life is finite. The current life expectancy at birth in the U.S. is about 79 years. Unless we die accidentally or else relatively quickly from a body system failure, our final decline may extend for years. We celebrate the optimism of our gradual beginnings, but we too often view a gradual ending as tragic or even an embarrassment.

Odd, since death is simply a part of our life's trajectory. Multiple Sclerosis and Parkinson's disease are examples of gradual motor degeneration. Various forms of dementia and some kinds of strokes characterize the gradual decline of awareness and reason.

Our motor system is about moving between here and there. Cognition is about effectively processing the past, present, and future.

## Motor Decline

Movement is a definitive biological system. Compare plants and animals, the two major biological groups. Plants don't have a brain and animals do. Plants don't have a brain because they're not going anywhere—and if you're not going anywhere, you don't even need to know where you are. What advantage is it for a rooted tree to realize that other trees are better situated for light/nutrients, or to notice approaching loggers?

On the other hand, an organism that has legs, wings, fins, and so on that permit mobility needs a sensory system to tell it about here and there. Then it needs a make-up-its-mind system to decide if there is better than here, or if here is better than there. Finally, it needs to activate its motor system if there is the better option, and it also needs a memory system to guide the return trip.

We humans spend much of our extended juvenile development period informally observing and exploring our motor system. We have to learn how to regulate and predict its movements and the movements of others and of moving objects. It's a complex system that must be activated/used for thousands of hours to reach the adult proficiency levels of complex movements. We've turned much of this juvenile practice activity into enjoyable play, and then follow it with participatory observable rule-based games.

Our mobility systems can even get us beyond direct physical movement. For example, our vocal apparatus can rhythmically move air molecules that hit the eardrums of others at a distance and create brain-to-brain language connections. Mastering the movements involved in spoken and written language is thus another major childhood task.

Young children get on a tricycle at three so that they can drive a car at 16, and they now similarly begin with video games at an early age so that they can begin to master Internet complexity by adolescence.

We're fascinated by those who move (or move objects) at virtuoso levels. The whole world gathers every two years to discover who can jump the highest, throw things the farthest, run or skate the fastest, or ski the best. We attend concerts to observe others sing or play musical instruments, and sporting events to watch others throw balls through hoops or to wide receivers. It may seem kind of foolish, but appreciating virtuoso movements in others is also quite human.

The childhood activation of our motor system generally involves planned sequences of arms and hands (reaching/grasping/throwing) before legs and feet (standing/walking) before articulate speech. Gradual motor loss typically follows the reverse order. Standing and walking problems lead to walkers and wheelchairs before we become bedridden—and this generally occurs before the loss of reaching and holding capabilities. Articulate speech is often the final loss of motor control.

## Cognitive Decline

Although we can observe the external dynamics of our brain's movement systems, cognition remains hidden within our skull (and our spine to some extent). We can currently only infer what happens internally before it becomes external behavioral movement. Parental nurturing and formal education have helped to guide us into the socially appropriate behavior that emerged from our many eons as a social species. That task has recently been made even more complex by increased population levels and by the emergence of a life enhanced by powerful portable communicative computers.

What do we know for sure? Our motor system is basically concerned about spatial relationships, here and there. Cognition seems primarily concerned about time relationships, the past, present, and future. Mastery seems to follow a trajectory in which we begin to understand the present during the preschool years, the past during the elementary school years (with its focus on language and a beginning awareness of our cultural heritage), and the autonomous future during our adolescent and early adult years (selecting and preparing for a vocation, selecting a mate, becoming independent, and so on).

This development prepares most adults for an extended qualitative life during which they make societal contributions commensurate with their capabilities and interests. They have children and/or support educational and social programs through taxes and contributions so that the next generations will have the same kinds of opportunities (or better) than those they had. Most people seem to have this wonderful Pay It Forward perspective.

Organisms evolved biologically to reproduce, rear their young, and then die. An earlier article in this series (Sylwester, 2013) suggested that the cognitive property that most differentiates humans from primates and other mammals is our ability to recognize and make analogies. Analogical thought identifies and uses common elements between an understood concept and one that isn't yet understood. This cognitive property provides the base for the imaginative explorations of complexities via the tools that fueled our success as a social species (science, technology, the arts, culture, government, and so on). A combination of these tools extended our life expectancy from the 47 years it was in 1900 to the 79 years it is today.

An extended lifespan allows many of us time to enjoy a life in retirement. But the retirement years can also be fraught with the disappointment of an extended and often painful motor and/or cognitive degeneration.

Cognitive thought drives motor behavior. Extended cognitive decline generally exists within the medical maladies called the dementias (Alzheimer's disease, frontal temporal dementia, vascular dementia, and so on). Further, many motor declines often also result in a form of dementia during the later stages.

Cognitive decline follows the same reverse order as in motor decline. The first system to typically decline is a sense of the future, the ability to plan for and execute behaviors. This is followed by a loss of the past, general and personal memory. The final loss is a sense of the present.

## Loss of Ability to Deal with Complexity–A Personal Story

My wife, who has suffered from dementia for seven years, is now periodically confused about where she is. She'll sit up in her bed and ask if we can get into the car and drive home so that she can go to bed. Showing her family pictures that were taken in our house, mail addressed to her at our address, and her clothes hanging in her closet doesn't dissuade her from her belief that this is not her home. These moments of place-confusion are fortunately balanced by more frequent periods in which she remains the delight she always has been.

We consider it irrational when a very intelligent woman who has lived in a house for 45 years no longer recognizes it. The reality is, though, that many supposedly intelligent people have irrational religious, political, and cultural beliefs, and similarly can't be rationally convinced of their error. Most of the rest of their life is normal and they often think that the 'others' are the ones with irrational beliefs. We've learned how to live with such folks, and we should similarly learn how to live compassionately with those who suffer from dementia.

The dementias have no cure on the immediate horizon. Thus, it makes sense to focus mostly on improving the quality of life of people with dementia, rather than on attempting to prolong life. This occurs when we genuinely accept their current situation and provide appropriate care. This could include (1) medical and nutrient supplements that enhance emotion/attention/cognition, and (2) a good understanding of the breadth of rational/irrational thoughts and behaviors. Hospice programs and Googling "understanding dementia" and "dementia assistance" can provide useful information on how to best help both the patients in decline and their families.

This late life issue has parallels earlier in life. People with Down Syndrome were formerly thought of as dysfunctional, but we've found ways in which they could become relatively independent, thus improving the quality of their life. Asperger's Syndrome is another example of a malady that contains cognitive capabilities within it that provide very valuable cultural skills. Seeking quality in all human life can thus be as important as extending it.

We often focus on the tragedy of the extended cognitive and motor decline of those with some form of dementia. It is equally important that we focus on the fact that these folks lived a lifetime during which they confronted and solved many complex challenges and made many positive contributions to their various worlds. That they can't continue to do so now doesn't suggest that they didn't live a life well spent. It is these lives well spent, in all their complexity, that we can and should celebrate.

Hunter Thompson (http://en.wikipedia.org/wiki/Hunter_S._Thompson) put it this way, "Life should not be a journey to the grave with the intention of arriving safely in an attractive and well-preserved body, but rather to skid in broadside in a cloud of smoke thoroughly used up, totally worn out, and loudly proclaiming, 'Wow! What a ride!'"

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