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From the Editor

Elan Leibner

Dear Readers,

This issue of the *Research Bulletin* is the second consecutive one devoted almost entirely to the theme of technology. Two of the articles are second installments of longer pieces, while all but one of the others are entirely new contributions. Every author recognizes this topic as one of the essential conundrums of our time. It is clear that the development of digital capabilities has created a void of corresponding moral and ethical capacities for using those capabilities appropriately, and, in one form or another, all of the articles grapple with this void.

Christof Wiechert, former head of the Pedagogical Section in Dornach, addresses the need for education to embed technology in the widest human context. Following Alvin Toffler's description of the three waves of technological innovation, Wiechert connects this sequence to Rudolf Steiner's evolution of consciousness. He argues for overcoming the one-sided intellectualization of society and education in favor of a comprehensive integration of the full range of human potential.

Jason Yates continues his superb treatment of current trends in technological development with the contemplation of artificial intelligence and virtual reality. Building on the theme of the digital gesture developed in the first article (*Research Bulletin* 21-2, Autumn/Winter 2016), he points at the dangers and assumptions, often indistinguishable from each other, that must be met and challenged if we are to maintain a humane and moral environment. Yates is an unusual "bird": a therapeutic eurythmist highly literate in technology who is a fine explicator of digital esoterica in a language that laypeople can understand.

Charles Weems is another unusual contributor. He has 40 years of college teaching experience in computer science and 28 textbooks to his credit. For the past 15 years he has taught at the Hartsbrook School in Massachusetts, and in his article he describes a curriculum he has developed for ninth and tenth grades. Weems is intent on bringing his students to a clear experience of the differences between a human being and a machine, and counts on this experience to help orient them toward their uniquely human tasks.

Harlan Gilbert meditates on similar themes. He looks for the tasks that technological development has placed before modern humanity and adds to the conversation an important theme: the redemption of the very beings to whom our technological devices have given an abode. He challenges us to cultivate the twin attributes of freedom and love and suggests some of the requisite attitudes that can lead us forward.

The second installment of Gopi Krishna Vijaya's contribution on Technology and the Laws of Thought enters directly into the historical evolution of thinking and logic. He shows with an abundance of examples and detail how the modern attitudes about the nature of thinking and consciousness evolved from Greek to modern times. He then points to the inherent flaws and holes in restricting the possibility for thinking to transcend its supposed limits. His essay is not an easy read, but those who persevere will be rewarded with fruits of a thoroughly researched and painstakingly mapped journey of our perception of the mind. It is a significant contribution to our theme of technology.

The final contribution dealing directly with technology is from the Research Institute's late co-director, David Mitchell. It is an article derived from a talk he gave in Norway in 2012 and stands up remarkably well to the changes that have come about since it was written. Mitchell was prescient in seeing the challenges, opportunities, and pedagogical implications of computer technology. He convened the first Waldorf high school teachers' colloquium addressing this topic in the late 1980s and was immediately concerned with incorporating and balancing, rather than avoiding or attacking, the emerging technological reality.

Lalla Carini reports on a survey she conducted regarding the way dyslexia is diagnosed and treated in Waldorf schools. She points out that schools differ greatly in the way they approach this important issue and that there is a need for teachers, therapists, and parents to work together in order to support students. We decided to include this report in an issue dedicated to technology because there is no question that the natural follow-up to a discussion of technology in a pedagogical context is therapeutic considerations. Though dyslexia is not directly attributable to the influence of technology, Carini's report can point the way towards a collaborative approach to all therapeutic questions.

David Scott, former Chancellor of the University of Massachusetts, reviews Jennifer Gidley's new book, *Postformal Education: A Philosophy for Complex Futures*. Gidley began her career as a Waldorf teacher and incorporates a deep appreciation of Steiner's insights into her discussion. She is a highly regarded academic in her native Australia and elsewhere. We are thankful that Arthur Zajonc, Board President of the Research Institute, suggested our publication to Dr. Scott.

Reports on the activities of the Research Institute for Waldorf Education close out the issue. Patrice Maynard reports on the many projects she is spearheading at Waldorf Publications, and Marianne Alsop reports on the rapid increase of the free resources available through the Online Waldorf Library.

Finally, a personal note: This is my final issue as editor of the *Research Bulletin*. I came onboard for Volume 16 back in 2011 and have enjoyed this task very much. The opportunity to sift through the research and the contributions has given me additional appreciation for the striving and integrity that people all over the world are bringing to their tasks as Waldorf teachers.

As editor, I have tried to shift the focus of the *Bulletin* from having been a publication that aimed to present Waldorf education to the academic community toward the needs of those who are our actual readers, namely practicing Waldorf educators. My guiding question has been: Is there a new thought in this piece, something that an experienced Waldorf teacher will find quickening for his or her work? With Douglas Gerwin, my late wife Tertia Gale, and me, we had three seasoned Waldorf folks who had to find something intriguing and worthwhile if an article was to appear in these pages. I hope that you, the readers, have indeed found the articles stimulating and supportive.

Douglas, Tertia, and Ann Erwin (layout) have been a terrific team with whom to work. The commitment they have for making sure that the T's are crossed and the I's dotted goes well beyond what my skill and patience could have managed. I also want to express my gratitude to John Wulsin, who took over as a guest editor for the previous issue while I was coping with Tertia's passing and left several pieces in the hopper for this issue.

Happy readings!

Authors who wish to have articles considered for publication in the *Research Bulletin* should submit them directly to the Editor at: waldorfresearchbulletin@gmail.com.

Technology and the Consciousness Soul

Ideas for Educators of the New Generation

Christof Wiechert

In this article I look at the development of technology and the Consciousness Soul in relation to the question of freedom and the future. I have chosen certain images, not for their own purpose but as illustrations of symptoms that point to transcendent realities working in and through them.

In his book *The Third Wave*,[1] written towards the end of the twentieth century, the futurologist Alvin Toffler describes how, for five thousand years and more, technology had no widespread impact on human life. Of course, there were technical inventions, but they did not significantly change our lifestyle and culture. To be sure, we know that during times of war, the ancient Greeks employed technical inventions such as burning projectiles that they lobbed into the vessels of their enemies in order to set fire to their sails. But when war ended, so did the use of these pyrotechnics. In other words, if you picture the historical timeline of technology as a function of daily life, that timeline remains pretty flat until the 18th century.

With the advent of the Industrial Revolution, technological inventions radically changed daily life and the formation of society.

With the advent of the Industrial Revolution, suddenly technological inventions are introduced to society that radically change daily life and the formation of society. In just a few years a new underclass, the proletariat, arises in Britain; mass poverty grips English society as a result of the steam engine, which assumes the human tasks of pumping water out of the mines, driving the machinery of the textile industry (the "Spinning Jenny"), and opening the doors to mass production. Soon thereafter come the steam locomotive and the railways. We cannot describe the history of the U.S. without acknowledging the influence of the railway tracks that, like long spindly fingers, stretched across the American continent toward the West, following the fleeing buffalo and Native Americans. A few years later came the internal combustion engine (the "Otto motor") and the Diesel engine, two inventions that dramatically changed the landscape of Europe and America.

Toffler names these industrial changes the "first wave," in which physical energy, the power of human muscles and human work, is replaced by machines. Soon thereafter comes essentially a second Industrial Revolution, but we do not use that name. With the harnessing of electric energy, we soon enter the age of the telegraph and later the telephone, telex, radio, and finally television. By this point, mass production is already the norm and nearly the whole world has changed its face through the introduction and use of electricity. Toffler names these electronic influences the "second wave," stating that its impact was felt less upon our physical energy and more upon our communication skills. Communication became machine driven—as we see it today in what we call "social media."[2]

Then Toffler, writing in 1980, predicted that, after this second wave, a third wave would emerge to replace our human intelligence with mechanized intelligence. And indeed, the computerization of our society in the late eighties and early nineties of the last century has brought us to a lifestyle today in which computers are a normal part of our life.

Toffler also predicted that the rate of these developments would speed up, getting faster and faster, to the point where we would be asking ourselves, Where will this end? Indeed, based on Toffler's work, we may ask ourselves, Will there be a fourth wave?

Before addressing this question, I would like to spool back to the endpoint in the flat timeline of technology when a huge spike in this line can be observed—a spike as high and as sudden as the Rocky Mountains suddenly jutting out from the vast expanse of the plains of the American Midwest. Is it possible to understand the source of this eruption?

The Poor Chicken

At the beginning of what historians call the Age of Enlightenment, a leading scientist of his day put a timepiece on a piece of wood, grasped a chicken in his left hand and, with an axe in his right hand, cut off the head of this animal, then watched his timepiece to see how long this animal would flutter around before it died.

Later he wrote that he would stretch Mother Nature on the rack and torture her secrets from her. In this brutal scene, we witness the birth of empiricism, in which nature became the object of a new kind of research. This research limited itself to those aspects of the natural world—namely its physical or material elements—that we can see and measure and from which we can draw conclusions through what is called an inductive method. This scientist strove strictly to separate himself as an individual and objective researcher from the object of his research. For him, the two had nothing in common. Today we honor him as the father of modern empirical science and as the pioneer of its method. His main scientific opus is entitled *Novum Organum Scientiarum*.

This empiricist was Francis Bacon, later Lord Bacon of Verulam, Lord Chancellor to the English royal court, and a high-ranking philosopher of the British Renaissance (1561–1626). Following years of research he wrote a novel in which he sketched a world of prosperity and peace in which people lived under the wise counsel of a Rosicrucian Leadership that guided society according to the rules of this new science. The book was *Nova Atlantis*, the first Utopia. Bacon died at the age of 65 as a consequence of one of his experiments: He wanted to know how ice could preserve meat, but caught a cold during his research and died of pneumonia. History is unclear whether he retained contacts with Rosicrucians on the European continent. But according to Rudolf Steiner, Bacon had an important mission to fulfill that was inspired by Christian Rosenkreutz, just as Shakespeare and Rembrandt had, too.[3]

* * *

I would now like to take a leap forward of 362 years to 1988, when, two years before his death and sick with leukemia, the American psychologist B.F. Skinner was sitting at his desk in the cellar of his home at Harvard and writing his last book.

As the inventor of programmed learning, programmed instruction, and the teaching machine, Skinner was world famous as an articulate spokesman for Behaviorism. Based on his famous lab experiments with pigeons and rats, among other creatures, he concluded that human behavior can be trained and by means of a very basic system of stimulus and response. Through this insight he developed a form of operative conditioning of human beings, intellectual but also social. He claimed that, using this method, it would be possible to condition humans to behave in socially desired ways. These ideas he had woven many years earlier into his first novel, entitled *Walden Two*—again, a Utopia. But he could not answer a basic question: Who should decide which behaviors would be the most appropriate. And now he sat at his desk to write his last thoughts. The title of his last and dark vision of the future was *Beyond Freedom and Dignity*. For this negative Utopia he was heavily criticized by Noam Chomsky, who, like other former students of Skinner, felt uneasy in the presence of Skinner and his ideas.

But in Skinner we see finally how the scientific method of empiricism targets the nature of the human being. The soul becomes defined as mechanical. In modern thinking everything on earth, in heaven, and in man is understood this way. Life processes, as well as social processes, are understood to be mechanical processes.

Since image-producing methods in neuroscience and psychology became popular at the end of the last century, since the unraveling of the human genome, the scientific method that started with Bacon has finally overwhelmed all disciplines in human biology and medicine.

The movement for humane psychology, initiated by Carl Rogers[4] in the 1980s, was virtually forgotten by the turn of the century twenty years later. In 2002 the *American Review of General Psychology* declared Skinner the most important psychologist of the 20th century, even ahead Freud, Jung, Piaget, and Adler.

Rudolf Steiner expressed the idea that in medieval times and before, the act of intellectual activity was experienced as a gift from outside.

Although the universities and their departments of philosophy continue to say that science, by definition, embraces a variety of theories, the dominant and undisputed approach is that of empiricism, or positivism, in nearly all subjects. Especially in the medical field but also in the arena of education, empirical scientific technology is mainstream.

Indeed, between the times of Lord Bacon and B.F. Skinner, step by step the scientific approach has come closer and closer to the realm of technology. Today technology and this form of science are seen as being identical. Science and technology have become an inseparable pair. (In the meantime they have developed a menage a trois, with economics or business as the third partner.)

Intelligence and the Individual

In art history it is well known that before the Renaissance it is hard to identify the names of great artists. Who designed the huge French cathedrals? Who built them? Who were the artists who made the marvelous stained glass windows in these houses of worship? Do we know the names of the designers of the patrician villas in Rome, with their floor heating and running water? Who invented the hot-air heating in these houses? In Rome there were hundreds of artists creating wall paintings and sculptures inside and outside the houses of the wealthy. Going even further back, who designed the Greek temples, the Egyptian pyramids, and most remarkably, who were the technicians who actually built them or who erected such simple things as the obelisks?

We know that we don't know, since all of these artistic and scientific works were completed anonymously. (There are a few exceptions, of course, in the works of Homer, Aristotle, Plato, Aeschylus, and a few others.)

Why is this the case? Could it be that during these ancient times the individual did not experience himself in his work as an individual? Is it possible that these masterpieces of art, construction, and design were not seen as the work of an individual person but as an expression of something else?

Rudolf Steiner expressed the idea that, in medieval times and before, the act of intellectual activity was experienced as a gift from outside. Ideas were believed to be not produced by man himself but as an inspiration from out of the spiritual world that came to manifestation in the mind or artistic creation of the individual thinker or artist. Not "I think," but "it thinks in me" was, according to Steiner, the general attitude and feeling.

And it was again Steiner who stated that from the 15th century on, step by step, this attitude was replaced by the experience, "I think. My thought is me." From there to "my brain thinks" is a small yet significant further step. It is the transition from inspirational thinking to brain-based thinking, or, in other words, from the brain as receiver to the brain as producer.[5]

For educators it is so important just to think this thought, just to realize there was a time, not so long ago, when man was not identified by his or her intellectual performance, but by what he or she did.

We live in the 21st century in the hypertrophy of intellectualism. Man is judged by intellectual performance, and its worth is measured and rewarded by a paycheck. The whole educational system depends on this modern (and false) premise. Every day now we see on TV and read in the newspapers that the world is depending less on human intellect and increasingly on other external powers, powers of artificial intelligence—and these are mostly powers of destruction.

Manufactured Intelligence and Inspiration

The wonderful thing about anthroposophy is that it widens our horizons into greater and greater perspectives. One of these perspectives is Steiner's idea of the Consciousness Soul. What does he mean by this soul? He is referring here to the capacity of each mature human being to use our individual intellectual powers in service to what our conscience says we must do. This is the step in development from what Steiner calls the Intellectual (or Mind) Soul to the Consciousness Soul. The task of the Intellectual Soul is to exercise the abstract thinking capacity and to make mankind ready to receive the intellect as an individual gift and tool. By contrast, the task of the Consciousness Soul (or conscience soul) is to use the intellect in a way we could call "responsibility for humanity." This enormous step in evolution began in the 15th century and it will need several hundred years more to mature completely.

Intellectual development is only one aspect of society. Other aspects are those dealing with emotions, actions, physical work, moral dilemmas, and challenges with social life as such.

What Happens to Inspiration (and Intuition)?

The best way to answer the question, "What happens to inspiration or intuition?" is to follow the explanations Steiner gave. As we have seen, intelligence was once understood as a capacity flowing into the human being from outside. Steiner called it a cosmic force; this cosmic force was given from the power of a cosmic being. Steiner identified that being as the one known in the Christian tradition as the Archangel Michael. Steiner continued to use this name. Cosmic intelligence was once held by Michael and was distributed to those who needed it. Steiner once spoke of Michael as the fiery-thought-king who in his evolution was seen (in the stories of the Old Testament) as the face of Jahve and in the New Testament as the face of Christ. The meaning of his name is a question: Who is like God?

It is not easy to feel and find words for the cosmic drama that unfolded as, step by step, the reins over intelligence slipped from the grip of Michael into the hands of human beings. Humanity was just starting to develop the Consciousness Soul in order to be able to hold that great power of intelligence.[6]

About fifty years ago human beings began to have the capacity to know that their powers of the intellect could either create or destroy our world. This is the responsibility of the newly developing Consciousness Soul. Why is this? It is because a part of the destiny of our evolution is freedom. And freedom exists only if there are choices. Now, science and technology can either destroy or build and develop our physical substance and the substance of our earth.

The same possibility will happen soon with the human soul as bearer of the "Human Identity." In Europe, an advertisement in the newspaper *Neue Züricher Zeitung* by the electronic firm ABB shows a nice young lady sitting at a lab table, and next to her a two-armed robot. The text reads: "ABB develops the 'you.me' technology. You (being the robot) and me (being the young lady)." And then follows this sentence: The Fourth Industrial Revolution has started. We see in this ad the integration of machines into the human being. The human intelligence alone is no longer adequate or advanced enough and must incorporate the robot's intelligence into her work. The implication is that the intelligence of combining human and machine capacity engenders "The Fourth Industrial Revolution."

The task of the Consciousness Soul is to use the intellect in a way we could call "responsibility for humanity."

Does this make sense to us? Is this our future? Life is now all about these questions. In fact it is the question of the future of our intelligence, of the intellectual capacities in man.

In education it is now normal to say we live in a society of the intellect—everything is about the intellect and the highest possible achievements there. This is what brings the individual to being recognized as the best possible member of society.

We can look at this from a different perspective and say, "Intellectual development is only one aspect of society. Other aspects are those dealing with emotions, dealing with actions and physical work, dealing with moral dilemmas and challenges, dealing with social life as such. If all these other aspects were directed solely by our intellect, we would end with B.F. Skinner's idea of a future society." That is the reason Rudolf Steiner repeatedly emphasized do not let the intellect develop alone! Give it a lifelong companionship of human feelings.[7] Or, as he stated it in another context, educate in a way that hearts start to think.[8]

The key to teaching classes on technologies would be to anchor them within the context of meaning and human relationships.

This would be a genuinely new kind of thinking, the new intellect: a thought life that is always accompanied by the qualities of the heart. (Here *heart* is used as a metaphor that indicates and includes a morally guided feeling life.) If that would happen, it would change the intellect's perspective of the future. This perspective, as it is now, has this design: An isolated intellect in man thinks it works for the good when in fact it produces various forms of evil. Isolated intellectual activity produces evil while convincing itself it is working for the better, for the good.

In this battle in which we are engaged nowadays, we see this force of the intellect in technology, in politics, in trade treaties, in the world of agriculture. Most currents in education today appear designed to prepare new generations for a life ruled by the isolated intellect.

The Answer of Education

It should be the mission of modern education to develop the intellectual powers ever in connection with other capacities of the becoming human being. From Howard Gardner we know that there are many more "intelligences" than the intellectual.[9] With the image-making tool available for research in neuroscience, the fMRI, we know that when children are engaged in an artistic activity, all parts of the brain are also engaged and "lit up." It is not so difficult to design a curriculum that is oriented to develop the whole human being, as well as the whole brain. The achievements of such schools as Waldorf (or Steiner) schools show that this is an option that already exists.

A new challenge in education is to find ways to develop in our youngsters an awareness of the ways in which scientific technology can creep into the smallest corners of their individual lives, turning them to objects for public consumption.

In North America there is a good program that offers to develop such an awareness, including helpful practices for young people. It should be taught in all practical skills classes [Ed. comment: This is a term used in European Waldorf schools for which we do not have an equivalent in North America] in the upper elementary and high school grades. This course is called Cyber Civics, a program that helps "students wisely and confidently use electronic technologies and social media."

Recently the British government commissioned research about the influence of social media on the wellbeing of children and young people, "Resilience for the Digital World: Research into children and young people's social and emotional wellbeing online." (Young Minds eNewsletter and Ecories). The programs developed from this research could be used in Waldorf schools, perhaps not at the early age that the research reports advise, but certainly from sixth grade on. They can also inspire Waldorf teachers to develop variations of these curricula, always following the idea that the human being is in command of his/her (technological) helpers, and that electronic devices are tools, not commanders. This is not at all a soft or sentimental subject, especially if one recognizes the devastating effects that habits of addiction have on children and adolescents. We have a growing body of evidence that documents levels of implicit or hidden addiction in the use of these technological tools, even among adults.

It should be the mission of modern education to develop the intellectual powers ever in connection with other capacities of the becoming human being.

Steiner advised high school teachers to devote at least one hour a week, starting in tenth grade, to the theme of technology. If we understand well the times in which we live, we could imagine that, from the sixth grade on, elementary schools could establish a weekly hour for the practical study of the most helpful and responsible uses of electronic devices and media. Students would be taught to use electronic tools and sources in a meaningful, responsible way, just as they have to learn to ride a bike and to drive a car. The key in teaching these classes on technologies would be to anchor them within the context of meaning and human relationships.

Summary

Rudolf Steiner's *Anthroposophical Leading Thoughts* (GA 26, 2002), which summarizes the results of Spiritual Science, concludes, not by coincidence, precisely with these questions about the relationship of man to technology. And we understand that this is precisely because *Leading Thoughts* ends with the future, our future. Perhaps it could be meaningful then to end this short overview with just these important (and prophetic) thoughts:

> "183. In the age of Natural Science, since about the middle of the nineteenth century, the civilized activities of mankind are gradually sliding downward, not only into the lowest regions of Nature, but even beneath Nature. Technical Science and Industry have entered sub-nature."

In other comments, Steiner defines forces of magnetism and electricity as coming from below the earth's surface—sub-earthly forces. He goes on to explain these are more difficult for us to manage than substances and forces that we use from the earth's surface. Hence his next thought:

> "184. This makes it urgent for man to find in conscious experience a knowledge of the Spirit, wherein he will rise as high above Nature as in sub-natural technical activities he sinks beneath her. He will thus create within him the inner strength not to go under.

> "185. A past conception of Nature still bore within it the Spirit with which the source of all human evolution is connected. By degrees, this Spirit vanished altogether from man's theory of Nature. The purely Ahrimanic spirit has entered in its place, and passed from theory of Nature into the technical civilization of mankind."

Those who study anthroposophy understand Ahriman as a higher spiritual entity who works to lead human evolution downward, away from the maximum development of individuality and individual freedom. This engendered Steiner's vision of an education designed to balance this "Ahrimanic spirit" with a human spirit re-connected to Nature, strong enough to utilize the high intelligence of Ahriman and mindful enough to cultivate warmth of heart and "heart intelligence."

ENDNOTES

1. Alvin Toffler (1928–2016). Two of his books are important in the context of this article, *The Future Shock* and *The Third Wave*.
2. There is a certain gesture in the fact that at Michaelmas, 1879, the first electric streetlights lit up Times Square in the heart of New York City.
3. Rudolf Steiner, "Man, being, spirit, soul," 3rd lecture, *The Science of Spirit and Modern Soul*.
4. Carl Rogers, (1902–1987). Famous psychotherapist, professor at University of California Berkeley. He stated that without empathy the doctor-client relation would not work. See: Counseling and Psychotherapy.
5. Within this context we can understand that Steiner criticized Descartes and his famous quote, "Cogito ergo sum," "I think, therefore I am." Steiner bluntly asked, "And when man sleeps, he does not exist because he does not think?" Steiner in *Study of Man*, second lecture, August 22, 1919.
6. Rudolf Steiner, *Anthroposophical leading thoughts*, (GA 26) The experiences of Michael in the course of his cosmic mission.
7. Recommend further reading: Steiner's lectures (GA 177) on "The Fall and the Spirits of Darkness."
8. Steiner, op.cit., "At the Dawn of the Michael Age."
9. Howard Gardner (2006). *Multiple intelligences*. New Horizons, completely revised edition.

Christof Wiechert *was a pupil at the Waldorf school in the Hague, Netherlands. After studying education and geography, he spent 30 years teaching at the Waldorf school in the Hague. During this time he was co-founder of the Dutch State Waldorf Teacher Training Seminar. For many years he was a Council member in the Anthroposophical Society in the Netherlands. Together with Ate Koopmans he developed the "Art of Child Study" course. He has lectured worldwide.*

Since September 1999 he has worked for the Pedagogical Section, from October 2001 to December 2010 as head of the Educational Department of the School for Spiritual Science at the Goetheanum in Dornach, Switzerland. He now continues to work for the School of Spiritual Science at the Goetheanum and on pedagogical and anthroposophical themes in different countries.

He is married with five children.

Beyond the Virtual Sensorium

Jason Yates

Introduction

In the first article of this series (*Research Bulletin* 21-2, Autumn/Winter 2016), I outlined a digital mode of thinking, or "digital gesture," that stands behind virtually every modern technological innovation. I traced the digital gesture from its beginnings in language and mathematics through to the sublime achievement of creating an artificial life form. It was suggested that an awareness of the digital gesture could be the basis for a healthy orientation within a cultural context increasingly dominated by digital technology and as a countermeasure against the threat of digital idolatry.

With the biases implicit in the digital gesture as a background, I will endeavor in this second article to unfold some of the experiences and current thinking surrounding the actual use of digital technology, with particular focus on virtual reality and artificial intelligence, two domains that are currently enjoying a renaissance fueled by Medici-an levels of patronage. Perspectives on the possible ramifications of digitally enhanced experiences for the future development of human beings will be explored in a third (and final) article.

A Bit of Personal History

When I was a teenager, the way I viewed and interacted with the world changed radically after I received an unanticipated gift: a Nintendo Gameboy. Although it was not as technically sophisticated as other portable video game systems of the time, the Gameboy was well-designed, had good battery life, and, most importantly, was bundled with a game familiar to almost anyone of my generation. That game, described on its cover as a "relentless building block video puzzle"—"From Russia with Fun!"—was *Tetris*.

The game's simplicity made it instantly playable. As blocks of different shapes fell from the top of the screen at an ever-increasing pace, the player had to rotate them mid-descent in order to form solid, horizontal rows that would then disappear from the playing area. If an unordered pile of blocks reached the top of the screen, you lost. If, however, you managed to get through all of the levels, you were rewarded with a crude animation of small dancing figures in Russian garb followed immediately by a space shuttle, rocket boosters and all, launching slowly into the digital sky: gravity overcome at last. And, other than the option of choosing a track of simple electronic music to loop endlessly while playing, that was it.

I played this game for an uncountable number of hours. And so did every other person I knew who owned the game. Technically speaking, one could also play with another person, taking turns to see who could reach the highest level, but I tried this on only a handful of occasions. For me, the best part of the game was that I could always begin again if I made a mistake, and, given sufficient time and concentration, that I could master the game completely. There was no ostensible reward, only total immersion in the act of playing.

Today, of course, to play a game of *Tetris* on a tiny monochrome screen capable of rendering only four (!) shades of gray would be a positively archaic act, reserved solely for the purposes of nostalgia.[1] Though I personally have no desire to play again, one memory associated with *Tetris* comes back to me with particular strength: I can vividly recall lying in bed after hours of game playing, closing my eyes, and seeing, not darkness, but clearly defined shapes of light that appeared to fall through my visual field. Over and over, they would appear, move, and disappear of their own accord, seemingly independent of my participation. I had no choice but to wait for the phenomenon to pass before finally being able to fall asleep.

I have had other experiences of similar phenomena in my adult life. I worked for a time as a 3D modeler, a job that entailed long hours of creating objects within a three-dimensional simulation of space generated by computer software. After a work session, I was able to close my eyes and see the contours of the shapes I had been constructing. I could rotate them in my mind's eye, viewing them from any angle. Or, again, after working for some time on an image in a computer-aided design application, I became accustomed to liberal use of the "Control + Z" key combination on my keyboard to "undo" any mistakes or to go quickly backward in time to a previous iteration. I would then find myself inwardly reaching for these keys immediately after making a mistake in the real world. Upon breaking a cup in the sink, for instance, I could quite literally feel an inner movement toward keys that were not there, accompanied by a strong intention to "undo" the event.

Investigators have begun to call the aftermath of gaming on everyday life Game Transfer Phenomena (GTP).

Virtual Afterimages

It turns out that I was not alone in having these experiences. Although I was unaware of it at the time, the tendency for developing phantom sense impressions following immersion in a game world had already been given a name by the late 1990s. Without any irony whatsoever, these and similar phenomena came to be known as the "Tetris effect," after an article in *Wired* magazine in which the author described his own encounter with the notoriously addictive game:

> No home was sweet without a Gameboy in 1990. That year, I stayed for a week with a friend in Tokyo, and *Tetris* enslaved my brain. At night, geometric shapes fell in the darkness as I lay on loaned tatami floor space. Days, I sat on a lavender suede sofa and played *Tetris* furiously. During rare jaunts from the house, I visually fit cars and trees and people together. Dubiously hunting a job and a house, I was still there two months later, still jobless, still playing. (Goldsmith 1994)

Such experiences are particularly impressive when one considers that they were precipitated by impressions resulting from a display that was less than four inches square and a game pad with two buttons.

That was then. Most modern games place much higher demands on the gamer's attention. How much higher? An experienced player taking part in a real-time strategy game must track dozens or even hundreds of independent variables, issue a variety of commands in multiple contexts using a full computer keyboard and multi-button mouse, and perform hundreds of actions per minute in order to be competitive with other players.[2] The psychological and sensorial effects of modern video gaming have only recently become the subject of empirical research. Investigators have begun to call the aftermath of gaming on everyday life Game Transfer Phenomena (GTP). One recent paper reports that out of a sample of over two thousand self-reporting gamers, 97% had experienced moments of GTP, which included:

> ...seeing game tags above peoples' heads, seeing maps in the corner of the eye, hearing music coming from the console when it is turned off, hearing voices in the head or coming from objects associated with the game, perceiving objects as distorted, feeling tactile

> sensations of game pads when not playing, confusing memories from the game with those from real life, and saying something from the game without intending to, etc. (Angelica B. Ortiz de Gortari 2016)

To reiterate: these are phenomena experienced in waking consciousness when not in front of a screen. The same study also found that as the time spent "within the game world" increased, so too the frequency of GTP outside it. Moreover, over half of the respondents who experienced the most severe effects reported the phantom sensations as being "pleasant" and more than forty percent specifically hoped that the phenomena would reoccur. Playing with the intention of escaping the real world also had a high correlation with severe GTP. Particularly striking is a similar survey that found that the few gamers who reported having *never* experienced any GTP also *never recalled their dreams.* (Angelica B. Ortiz de Gortari 2015) Put the other way around, only those having an active dream life were susceptible to the hallucinatory effects of their gaming sessions.[3]

Immersion in virtual reality creates immediate bodily sensations that are closely entrained—in real time—to simulated events.

Virtual Reality

Like the internet, virtual reality, or VR, sprang into existence in answer to a problem perceived by the U.S. military. And, like the internet, VR has grown well beyond the problem for which it was originally conceived. So much so, that heads-up displays—designed in the 1960s for multi-million dollar fighter jets—have now arrived at a smartphone near you. Or, at least, something like their great-grandchildren has. In aviation, the heads-up display eliminated the need for cramming a large display screen into a small cockpit by creating a "virtual" screen that appeared to float in front of the pilot's field of vision. When combined in a helmet with sensors capable of tracking head movements, the virtual screen also elegantly solved the problem of aiming ordnance that otherwise had no direct relationship to the pilot's body. The next logical development was to create flight simulators that required no physical relationship to any kind of real equipment at all (aside from the simulator, of course).

Which brings us to the present moment. The most conspicuous accoutrements of VR are relatively well known: head-mounted displays, data gloves or suits that track movement, and handheld input devices with force feedback. Until very recently, these types of hardware were largely consigned to the world of academia due to their high cost, bulkiness, and processing demands. Today they are available on Amazon.

Almost three years ago, Google released a product dubbed "Cardboard" as a proof-of-concept meant to demonstrate the growing capabilities of its smartphones and generate interest in VR. "Cardboard" consists of two inexpensive lenses mounted in a piece of precision-cut cardboard that can be folded into the form of a head-mounted display (HMD). A smartphone fits into the HMD and, using a compatible app, the phone's display is divided into two smaller images that appear as a single three-dimensional image when viewed through the HMD's lenses. Contemporaneously with Google's foray into VR, Facebook spent two billion dollars to buy a small startup company that was poised to release its own HMD. Now a commercial product, the high-resolution "Rift" headset has integrated speakers and movement sensors capable of producing fully immersive VR experiences and costs less than a midrange laptop.

Microsoft, by contrast, is following a somewhat different path when it comes to the future of digital enhancement. Its HMD—called HoloLens—is designed to augment the real world rather than simulate a virtual one.

The HoloLens is a self-contained "holographic computer" that allows the user to see through its semi-transparent screen into the real world where three-dimensional "holograms" appear to be projected onto objects and surfaces. Using the device, an architect can, for instance, have a fully realized model of a building appear on the kitchen table, complete with simulated people, trees, and shadows. Moving around the table in the real world yields the user views of the virtual building consistent with its orientation on the table. Or, because the device can track a user's hand movements, the model can be rotated by reaching out and "moving" it into a different position on the table. If VR simulates a whole world, augmented reality (AR) creates "real" hallucinations in the ordinary world.[4]

Hierarchy of Simulation

Strictly speaking, even when portrayed in two dimensions, all video games are a kind of virtual reality; they purport to show shapes and movements where there is neither.[5] What is *actually seen* in a game world—if it is to hang together as any kind of world at all—are simulacra of objects and laws that can be found in the "real" world. Look away from two-dimensional simulations, however, and the perspective changes. Within the hierarchy of simulation, proper three-dimensional virtual reality belongs to the upper echelon. In immersive VR, the simulacra take on characteristics beyond those attributes found in phenomena of the outside world. In VR, *the sensation of presence itself* is part of the simulation.

Companies heavily invested in artificial intelligence face the possibility of developing "moral algorithms."

Maintaining a connection with the real world is relatively easy when looking at a traditional computer screen. Even if the content onscreen is simulating three-dimensional space, one still "knows" that it is "just a simulation." All one has to do is look behind the screen to see that "there is no there there," as Gertrude Stein once put it. But, when the movements of the head are integrated with the visual and auditory systems through binocular and binaural simulations, the illusion of being present in a virtual world can be overwhelming. It is nearly impossible to describe the experience of fully immersive VR. It is, quite literally, awesome. People experiencing it for the first time will often react emotionally by crying out, or viscerally by losing their balance (or lunch), or psychologically by losing all sense of time. Unlike "game transfer phenomena" which manifest as aftereffects, immersion in VR creates immediate bodily sensations that are closely entrained—in real time—to simulated events.[6]

Enter Artificial Intelligence

Reserving three billion dollars for "human-machine combat teaming" (a.k.a. "Centaur Warfighting") doesn't seem like much of a commitment by the Pentagon's standards. Nevertheless, it is a clear indicator that the U.S. military is again helping foment a sea of change. If the goal is to maximize efficiency in warfare, the logic of combining artificial intelligence (AI), human beings, and weapon systems is difficult to refute on its own terms: Let the humans do whatever they are good at, and let the digital gesture hold sway when ultra-fast, highly-coordinated precision is called for. Just as it is much less expensive to train pilots on flight simulators, it is also more cost-effective for combat drones to make some of their own decisions without the constant human oversight that they now require.

The moral oblivion of such a scenario is already being normalized in Silicon Valley as companies heavily invested in AI face the possibility of developing "moral algorithms." Google's self-driving cars are a case in point. A recent paper in *Science* asserts that "the algorithms that control [autonomous vehicles] will need to embed moral principles guiding their decisions in situations of unavoidable harm."

(Bonnefon et al. 2016)[7] Engineers who actually work on the technology, however, are often quick to point out that, since AI doesn't think like a human being, the possibility of causing harm in the first place can be mitigated through technical virtuosity. After all, self-driving cars have yet to injure a single person despite having driven hundreds of thousands of miles autonomously.[8]

In addition to a having a stellar driving record, AIs based on "deep learning" techniques have already bested human beings at games of chess, Go, and the game show *Jeopardy!* Although all of the examples mentioned so far have emerged from research done in the U.S., machine intelligence developed through deep learning techniques is not unique to the West. A strategic plan for artificial intelligence released late in the Obama administration identifies China as the leader of new publications in the field.[9]

By discerning the thread spun by the digital gesture, educators who recognize the free, human spirit as alone capable of moral action may confidently lead even digital natives out of the labyrinth.

Education and the iGeneration

Millennials, the original digital natives, are already well into adulthood. The subsequent generation of children—Generation Z or the "iGeneration"—are now, or soon will be, entering school age. While there is, of course, no consensus as to how current and future generations will fare in their encounters with digital technology, there is a growing chorus of influencers who see the digital enhancement of the human being as crucial, not just for the progressive evolution of humankind, but for its very survival. Marc Prensky, a well-known author and speaker on the subject of education and originator of the term "digital native," claims that "the brains of wisdom seekers of the future will be fundamentally different, in organization and in structure, than our brains are today." By becoming enhanced through the use of digital technology, he has predicted that a *"homo sapiens digital"* will evolve and be capable of insights to which "the unaided mind will be blind" (Prensky 2009).[10]

Elon Musk, the billionaire entrepreneur and advisory council member to the Trump administration, shares a similar sentiment. Musk recently told an audience at the World Government Summit in Dubai that he expects to see a "closer merger of biological intelligence and digital intelligence" if the human race is not to become obsolete in a world of artificial intelligences. More provocatively, he has also argued that, given the rapid gains in the last few decades—from *Tetris* to photorealistic 3D games with millions of simultaneous users—it will not be long before games "become indistinguishable from reality." Following the trajectory of his own logic and taking into account the fact that evolution works on exponentially longer timeframes, he ultimately concludes that "the odds that we're in base reality is one in billions." Meaning: We are most likely already living in a simulation created by higher intelligences.

Fortunately, not all thinkers regard human evolution as technologically pre-ordained. In an essay titled "Intellectual Field or Faith-based Religion: Moving on from the Idea of 'Digital Natives'," authors Sue Bennett and Karl Maton rebut popular ideas about children "growing up digital." After challenging Prensky's ideas regarding *homo sapiens digital*, the authors sum up:

> The argument that technology is changing our society is the weakest of truisms on which to rest arguments for radical change to current systems and practices. It may not be as sexy to proclaim evolution rather than revolution, or to highlight diversity rather than paint stark differences, because such notions require

> measured, rational, and sophisticated thinking, and a tolerance for ambiguity and careful consideration rather than sloganeering. Yet this is what the evidence points to, and this is the thinking demanded of us. (Thomas 2011, p.180)

Without an enthusiastic challenge furnished by a true spirit of inquiry, those who, in the name of progress, would yoke human beings to machine intelligence may find their task all too easily accomplished. Foreshadowed by the concepts inherent in "moral algorithms" and simulations "indistinguishable from reality" is a world in which the faculty for moral imagination may matter less than the tireless, unblinking eye of a digital intelligence. By discerning the thread spun by the digital gesture, educators who recognize the free, human spirit as alone capable of moral action may confidently lead even digital natives out of the labyrinth.

ENDNOTES

1. Feeding nostalgia for old 8-bit games has become big business. At the end of 2016, Nintendo released the "NES Classic Edition," a miniature version of its iconic Nintendo Entertainment System originally released in 1985. The new version comes with over two dozen of the most popular games from the late 1980s that play, sound, and look exactly like the original games. A reported 1.5 million units were sold in less than four months, and ongoing demand has led to worldwide product shortages.
2. The current world record for the number of actions per minute (APM) in a real-time strategy game is held by Park Sung-joon, a 30-year-old professional gamer. During a world championship competition he once reached an APM of 818, which is more than 13 actions per second.
3. The 2016 article already mentioned summarizes several other dream recall studies as follows:
"In general, incorporation of video game elements in dreams about video games are [sic] often reported by gamers, and gamers that have experienced GTP have reported similar content in their dreams. ... Moreover, absorption and fantasy proneness have been associated with high recall of dreams. These overall findings suggest that it is opportune to investigate sleep disruptions, working memory, attention abilities, and fantasy proneness variables in future studies of GTP." (p. 281)
4. Sometimes the term "Mixed Reality," or MR, is used to describe the use of digital technology to overlay virtual elements onto a view of the real world. A company called Magic Leap is building a mixed reality device that is not yet for sale. In lieu of using a binocular or "holographic" approach, the Magic Leap device creates solid-seeming objects that "intersect" with the real world by projecting digitally controlled patterns of light directly onto the user's retina. By eliminating the visual abnormalities associated with stereoscopic displays, virtual retinal displays do not cause virtual reality sickness, symptoms of which resemble motion sickness. The retinal approach also creates images of a much higher resolution and visual quality. One reviewer of a Magic Leap prototype describes his experience:
"Intellectually, I know this [object] is an elaborate simulation, but as far as my eyes are concerned it's really there, in that ordinary office. It is a virtual object, but there is no evidence of pixels or digital artifacts in its three-dimensional fullness. If I reposition my head just so, I can get the virtual [object] to line up in front of a bright office lamp and perceive that it is faintly transparent, but that hint does not impede the strong sense of it being present." (Kelly 2016)
5. Does a series of light bulbs lighting up one after the other constitute movement? Like a row of bulbs, the pixels in screen media are fixed and can only brighten or go dim; unlike a reel of film moving through a projector, pixels are unable to move relative to the light they emit.
6. Leveraging the powerful experiences afforded by VR has already proven to be an effective treatment for several medical conditions, particularly pain control management and the treatment of post traumatic stress disorder. One VR engineer successfully created a virtual world that cured his own strabismic amblyopia, a condition which was formerly thought to be incurable in adults. (Blaha & Gupta 2014)
7. The authors of the paper have launched a website called "Moral Machine" (moralmachine.mit.edu) for the purpose of "gathering a human perspective on moral decisions made by machine intelligence."
8. Well, not quite autonomously. There was a human being riding shotgun for nearly all of the miles driven by Google's cars. The company has admitted that its human overseers have had to take over "many thousands of times" for one reason or another.

9. A PDF of the strategic plan can be found at: https://www.nitrd.gov/PUBS/national_ai_rd_strategic_plan.pdf
10. Many believe that VR will play a central role in this evolution. Tom Furness—the man who, in addition to inventing most of the other technologies enabling VR, created the first helmet-mounted displays for the US Air Force—has founded the "Virtual World Society" (virtualworldsociety.org) in an attempt to beat the swords he helped create into plowshares. One of the organization's aims is to "turn the living room into the learning room" by introducing children to VR at an early age. Furness believes that VR is a "transportation system for our senses" that will "unlock intelligence and link minds." Referring to virtual reality's power to create bodily sensations of being "present," he says, "When you put people into a place, you put the place into people." That is, people remember what they learn in the virtual realm because they actually "embody" what they experience there.

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Computer Science for Ninth and Tenth Grades

Charles Weems

In *A Modern Art of Education*, Rudolf Steiner says, "People are surrounded by inventions of the human mind, but have no contact at all with them. It is the beginning of an antisocial life simply to accept inventions of the human mind without at least understanding them in a general way. … At the age of fourteen or fifteen, we must focus our energy on connecting children with the inventions of the human mind. This helps them understand and find their place in society."[1] Digital technology is perhaps the most characteristic and multifaceted invention of the human mind in the present era. It is overturning social norms at a rapid pace. Thus, Waldorf high schools owe it to their students to implement developmentally based instruction in computer science (CS) that is suited to all students in all grades, not just elective courses for those who are predisposed to have an interest in the subject.

Waldorf high schools owe it to their students to implement developmentally based instruction in computer science.

Traditional high school CS instruction takes its shape from introductory college courses. There are two CS advanced placement (AP) exams, one of which matches a typical introduction to a programming course that uses the Java language. The other, called CS Principles, is a non-majors overview of the field. These AP exams follow the principle that the earlier a subject is taught, the faster students will progress to more advanced subjects.

As Waldorf teachers are well aware, however, this is not the best practice for truly effective teaching. Rather, it is better to work with students in ways that meet their current developmental stage. Thus, in each year of high school, we have an opportunity to create different encounters with technology that build upon one another, while leaving concepts open so they can grow.

There are many ways to achieve this goal. Various authors have addressed approaches to teaching CS in Waldorf schools over more than two decades.[2–7] Some begin from the traditional questions of what, how, why, and who that we associate with the four high school grades, while others seek to address the thinking, feeling, and willing aspects of the human being. Jamie York's survey,[3] as well as my own research into online descriptions of curricula, has also found that some schools are more focused on computer skills (typing, word processing, digital photography, etc.). While some place CS in a main lesson, others schedule it into track classes with varying amounts of time allocated. It may be a requirement in all four grades, an elective in one grade, or a mixture.

In addition to pedagogical guidance for teaching about technology, Steiner gave his perspectives on its spiritual aspects in different contexts: for example, its relationship to art and culture,[8] the nature of elemental spirits associated with it,[9] and the nature of number, weight, and measure.[10] He describes how technology draws us more deeply into materialism, and although this is a necessary step for human evolution, the being that inhabits technology makes it more difficult for us to connect with the spiritual path leading upward. Seemingly in anticipation of modern experience, he says that when people come together through technology, it leads to conflict and destruction. Steiner makes it clear that technology poses a threat to our humanness if we don't consciously take up our relationship to it and develop a mindset and practices that help us to keep it in proper perspective.

As digital technology advances rapidly, it is good to periodically revisit our approaches to teaching computer science. It is also worth noting that other parts of the curriculum, especially the humanities, present opportunities to better support the students in finding their way through the fog of technology and toward a path of evolution that leads humanity upward. If instructors who work with those subjects will take the time to immerse themselves in the digital landscape, they will find obvious connections that can enliven their efforts and make them even more relevant to the students of today.

Steiner makes it clear that technology poses a threat to our humanness if we don't consciously take up our relationship to it.

Any curriculum design should begin from consideration of the students (we teach students, after all, not subjects). What is it that we wish to achieve for them? What can we give them of lasting significance for their lives? What do we try to help them develop inwardly as human beings through the encounters and experiences we provide?

Technology offers tremendous benefits to society, but it also comes with many pitfalls. The goal of a CS curriculum should be to help students find a healthy, moral relationship to this artifact, so that they can use it to good effect in the world and not fall prey to its darker side. In this way they gain an understanding that permits them to see it as it truly is, in its different guises and manifestations.

Course content for a Waldorf high school class should also arise from the teacher's expertise, in combination with an understanding of anthroposophy. While we can take inspiration from the work of other teachers, we must be careful to avoid simply replicating their lessons. For the material to live in the students, it must first live in us. And we must constantly evaluate our own efforts and refine them, especially in a subject that is changing from year to year.

Thus, the examples given here should not be seen as prescriptions. They are a work in progress and are shared at this point merely to stimulate creative impulses.

For context, I am a professor of computer science—with forty years of college teaching and fifteen years of Waldorf high school teaching experience—and co-author of twenty-eight introductory textbooks; I have designed and built advanced computers from the design of custom chips to the construction of working systems. The classes I teach in each grade are offered in two forty-five minute periods per week for a trimester that varies from nine to thirteen weeks in length, depending on the school calendar.

A common theme among prior efforts has been the revelation of the inner working of the computer: for example, building an adder from electromechanical relays. It is indeed important for students to develop an understanding of how the hardware works. Fundamentally, computers are very simple machines made from switches that turn on and off, just like those that control lights or ring doorbells. If the switches are arranged in a fairly simple manner, they can be made to operate in a pattern that mimics the pattern of 1s and 0s that appear in a base two addition table. Experiencing this reduces the magical, vaunted machine to something that can be grasped by mere mortals.

Early on, I tried the relay adder lesson in tenth grade. However, relays were hard for the students to understand. They were more focused on the novelty of the device than on what the circuit was doing. It was a leap to grasp the interconnectedness of the relays. Yet, I wanted this "how" aspect of computer science to precede the Electricity and Magnetism block that follows in eleventh grade.

Relays illustrate a particular aspect of digital switches: namely, that the circuit controlled by one switch can in turn flip another switch. While this is an essential element in the automatic operation of a computer, it is not a pattern that most people encounter in ordinary life. People press buttons. Buttons don't press each other.

Thus, it is necessary to temporarily set aside that aspect of digital logic and have the students do all of the button pressing themselves. They are given boards that hold batteries, a light, and doorbell buttons that are either wired in parallel or series (logical OR and AND), or a normally closed button (NOT). Each student is responsible for pressing one button. They are told to do so either in response to an input value, or to a light on another board. With two AND boards, an OR board, and a NOT board, they are able to mimic the operation of an exclusive OR (using OR to mean you can have ice cream "or" cake, but not both). Exclusive OR is otherwise known as a half-adder because it has the same pattern as adding two bits of a binary number, if there is no carry from the place to the right.

The goal of a CS curriculum should be to help students find a healthy, moral relationship to this artifact so they can use it to good effect in the world.

With this exercise, it is possible to convince students that switches can mimic arithmetic. They can then be shown a spring-loaded electro-magnetic solenoid that moves a plunger back and forth as it is turned on and off. It is easy to imagine its power leads being connected in place of a light on one of the boards, with the plunger positioned to push a button on another board, thereby replacing the student's eyes and fingers so that the whole thing becomes automatic.

From here, I tried introducing breadboards with small-scale logic chips, so that they could wire up an adder that also accepts a carry from the right. But it was too great a step to go from doorbell buttons and solenoids to imagining the equivalent arrangement hidden inside a black plastic rectangle with protruding wires. Learning to use the breadboard itself was also a distraction.

Strangely enough, the bridge between the two was a logic design program called Logisim.[11] In trying it, I was concerned that wiring together gate symbols on a screen would be too much of an abstraction. But today's students are very comfortable with seeing icons on a screen as representations of concrete objects. They quickly grasp the use of the program and enthusiastically start wiring up and testing circuits. Some even come in the next day having invented more sophisticated circuits at home.

Once the adder is functioning, a simple cut and paste operation enables them to wire together multiple copies, resulting in a multiple digit adder. The students feel a sense of mastery in seeing their creation solving binary addition problems that they had only recently found challenging. With this experience behind them, it is much easier to envision the gates from their simulation residing inside the chips on the breadboard, and then wire them in the same way.

Teams of two build and test their adders, then connect them to other teams' adders, gradually extending the chain as more teams join in. There is considerable excitement as they flip the input switches and see their construction adding binary numbers. We then go back to the logic simulator and see how a memory circuit functions before assembling it on the breadboards.

Seeing these different circuits, the students are impressed with the number of switches that are involved, which is part of what gives the computer its power and basic character: simple arrangements of switches, replicated many, many times. We then reflect on the number of doorbell buttons in each gate and calculate the number of switches that would be present in the register memory of a typical 64-bit computer. The numbers become staggering.

Frequently, the experience of calculating the number of switches prompts a student to question how they are actually built. With some wafers and bare chips, as well as some photographic negatives to lend a concrete support, it is possible to illustrate the photolithography process used in making chips. While the functioning of transistors is still beyond their understanding of electricity, they can see how it is possible to form wires in different layers to interconnect the switches.

The process of painting on a material, coating it with a photosensitive layer, exposing and developing it, then using a chemical to dissolve away unexposed areas is conceptually simple. Hearing about the precision and cleanliness involved helps them to appreciate the effort that goes into making the circuitry in their computers and phones.

By the end of tenth-grade computer science, students have the sense that nothing in the computer is beyond their understanding if they choose to devote more time to studying it.

As other authors have noted, disassembling old computers in tenth grade seems to be a natural match for this age. Learning to use a variety of tools, the students gleefully attack these formerly expensive machines. As the components come out, they ask what they are and how they work, which provides many teachable moments. At the end of this process, I have them sort the pieces on separate tables: one for the processors, another for the memory, a third for the disk drives and other peripherals, and a fourth for the supporting hardware (power supplies, fans, cases, motherboards). Students are always surprised to see that the actual processor is a tiny fraction of the whole, and that much of what we think of as a computer is only there to enable us to interact with it.

By the end of tenth-grade computer science, students have the sense that nothing in the computer is beyond their understanding if they choose to devote more time to studying it. They also appreciate that computer technology is the result of decades of work by many people, building upon others' efforts, and that it is amazingly inexpensive, considering what it takes to manufacture it.

If time permits, I have the students program a microcontroller to turn on a light, using assembly language. I give them the code, which is just a few lines long, and explain what the instructions do. The point is not to learn to program, but to see that when a program moves a binary 1 into a particular memory location, it is turning on a circuit that illuminates a light, just as our doorbell buttons do. This comparison serves to connect the very abstract idea of a program to the concrete actions of switches.

Also in tenth grade, we hold a separate computer skills class in which we look at how to distinguish reliable from unreliable sources of information, as well as covering the basics of word processing, spreadsheets, and presentation software.

Much of what is covered in tenth grade depends on the foundation that was built in the ninth grade class. As others have previously documented, the "what" question can be addressed by defining the word "computer" and by demonstrating how binary numbers meet the polar-reasoning aspect of this stage of development. However, there are deeper aspects to the nature of digital technology that also lend themselves to this kind of reasoning, making it possible to examine more carefully what a computer is.

Before we attempt a definition, we explore what computers can and cannot do. The first list tends to be quite lengthy, and it is more challenging to find tasks that the computer cannot accomplish. Out of the discussion it emerges that many of these tasks—having emotions, thinking, reproducing—are essential qualities of being human, and this insight sets a tone for the class: Humans and computers are very different. Our goal is to experience just how different they really are.

In defining a computer, it can be described as being digital, but most students haven't considered what that means. For this reason, we explore the nature of numbers as being concepts we represent symbolically so that we can communicate them. The computer uses another representation, which is still not a concept. Only humans hold numbers as concepts.

Computers, however, represent a particular kind of number, called *discrete numbers*, which need to be distinguished from *continuous numbers*, which is how human beings can think about them. For phenomena of the world to be represented in the computer, they need to be divided into discrete units that can be measured, weighed, or otherwise converted into discrete numbers. Often there may need to be a preparatory step of converting the phenomena into an electrical analog prior to being split up.

Thus, we find the ultimate polarity between humans and computers: We are alive and they are dead.

For example, variations in air pressure associated with a sound are transformed into an electrical signal by a microphone. The signal is then divided into time units, and its voltage within each unit is measured to produce an integer value within a given range. The image formed by a lens falls on a material that generates electricity in proportion to the light it receives during the period the camera shutter is open. The material is divided into squares, and the charge in each square is measured to give a corresponding integer for that patch of the image. Zooming in on a digital image always reaches a point where the squares are visible, unlike what happens when a human takes a closer look at an object.

As students experience the process of digitizing different phenomena, they gain a deeper sense of how computer representations differ from human experience. They also see the significance of numbers in the computer, which then sets the stage for an introduction to binary arithmetic. In teaching binary arithmetic, it should be kept in mind that most students will never make practical use of it. Thus, the reason for learning it is to experience how simple it is. The challenge is not to understand the operations, but to let go of the mental habits of decimal notation. We have to return to the basic questions: What are digits? What is counting? What is addition?

With just a little practice, students can see that it is possible to change decimal numbers into binary and vice versa. The binary addition table (which has just four entries) is much smaller than the decimal table. Tens complement subtraction is also simpler than our modern algorithm, although it takes some practice to get accustomed to it. In binary, it becomes a trivial extension to addition. The binary multiplication table is also much easier to learn, and multiplication is seen to be another minor variation of addition. Students thus see that computer arithmetic has minimal rules that are applied mechanically, without thinking.

In tenth grade, the students implement the addition table using the boards with doorbell buttons. The emphasis is not on understanding the operation of the circuit, but rather on simply experiencing that a simple set of switches can mimic arithmetic. Thus, a computer is seen as a device built from switches that flip in patterns that correspond to doing arithmetic, which is vastly different from how we think.

The last remaining piece that defines a computer is programming. We use the old Bell Labs CARDIAC, a cardboard simulation of a computer, to visualize the major components of a computer.[12] Unlike Setzer's paper computer,[13] which involves active role-play, the CARDIAC has a flowchart and sliding tabs that lead each student through the process of fetching and executing instructions in a program.

The goal is not to teach students how to program, or how the computer works, but rather to give them a sense of what it is like for a computer to execute a program. It is an intentionally tedious and mind-numbing exercise in which students see how little is actually done by each step in the program. Computers are able to do what seems to be so impressive because they can carry out billions of these tiny steps each second. The challenge of the exercise is to resist the urge to think, and instead to mindlessly follow the instructions. This exercise drives home the point that computers do not think.

At the end of the course, students are asked to summarize what a computer is by writing a first-person essay in which they pretend to be a computer explaining itself. They draw upon their understanding of discrete versus continuous, digitization, binary arithmetic, switches, and computer operation to creatively describe computer existence. Once they have completed this assignment, we have a discussion of what it would be like for a computer to be instructed that it was about to be rebooted and turned back into a "normal" computer.

Inevitably, the conclusion is that it would be like awaiting death. Thus, we find the ultimate polarity between humans and computers. We are alive and they are dead. By ninth grade, students have already been exposed to fiction, games, and marketing in which computers are made to seem lifelike. It is thus important to dispel that notion so they can see them for what they truly are: inventions of the human mind.

With that as a foundation, computers become objects for study. We can learn how they work, use them as tools, understand why they are unreliable or vulnerable to hacking, and eventually explore who we are in the context of a society that depends on them.

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Computers and Intelligence

Harlan Gilbert

Each year brings new and startling examples of computers emulating what we think of as intelligent behavior. For a long time, they have controlled machines, performed secretarial tasks, and kept track of budgets. More recently, they have begun to beat even the best players at games such as chess and *Jeopardy!*, to respond—sometimes even quite reasonably—to enquiries, and to care for the elderly. In the face of such convincing achievements, it is easy to assume that there must be some form of intelligence present and active in the computer. On the other hand, they are still machines, and what kind of intelligence can a machine have?

Because we can see the workings of simple mechanisms such as mousetraps and grain mills, we are not normally deceived into thinking that these are anything but purely mechanical devices. As technology becomes more sophisticated, however, we can no longer observe its workings, nor can non-specialists readily comprehend the principles by which highly complex electronic devices operate. It is therefore easy to lose sight of their character as machines. Because our intelligence can no longer follow the workings of the technology that produces the results we see, it is easy to believe that these devices show signs of intelligence. Because they are not simple mechanisms, their nature simply as mechanism becomes more difficult to discern.

Because our intelligence can no longer follow the workings of the technology that produces the results we see, it is easy to believe that these devices show signs of intelligence.

Computers show a range of actions and reactions that often lead us to use the term "artificial intelligence." It is a short step from here to go on to ascribe actual intelligence to them. What is the difference between actual and artificial intelligence?

An analogy may help. We know that mousetraps can react to the presence of mice. Most people attribute neither a hunting instinct nor a pleasure in the kill, nor an intelligent plan to a mousetrap. It is obvious that its working is purely mechanical. Because mousetraps are quite simple mechanisms, it is readily apparent that they are endowed with neither intelligence nor a feeling life. This case is a useful reminder that actions or reactions analogous to those of organisms imbued with an inner life in no way prove the existence of instincts, feelings, or intelligence.

The Simulation of Intelligence

To understand the actual nature of the phenomenon often referred to as "artificial intelligence," it will help to review the origins of computing devices. Alan Turing, an early theorist of these devices, laid down principles to which all modern computers still conform. The archetypal computer can be described as a series of digital states (imagined as a row of lights, perhaps a very long row, each of which is either on or off at any moment) and a linear "tape" of information. This "information tape" consists simply of a series of positions, each of which is either punched or not punched (marked or not marked). With each position that the computer encounters on the tape, the computer's state (lights) may change, but only according to certain pre-determined and fixed rules. The limitation laid down is that the new state of the computer after this encounter (its new pattern of lights) must be completely determined by the operation of these fixed rules upon the computer's current state and the tape position currently encountered. After each of these occurrences, the tape may also be moved forward or backward one position; this too must be dependent upon fixed and predetermined rules.

Despite some superficial divergences, modern computers still essentially conform to these original principles. That is to say, every digital computer operates according to (and only according to) a sequence of mechanical operations defined by its construction. There can be no question of attributing any more actual intelligence to any one of these highly complex, but still essentially mechanical, reactions than could be attributed to the action of a mechanical loom or typewriter.

We must learn to look at computers and know that there is no intelligence there, simply a cleverly made recording of intelligence, subject to all the limitations of any recording and, above all, to the limitations of its fashioners.

Intelligence presupposes the ability to conceive the world in various ways. Aristotle categorized four fundamental aspects of the world: Everything can be seen to have a purpose in the grand world plan, an originating cause, a form, and a material composition.

Intelligence consists partly in having a fluid, playful relationship to these four ways of conceiving the world. Human intelligence understands, or can come to understand, each of these modes of understandings' contributions to the current situation and can adjust its relationship to them, both sensibly and creatively—that is, intelligently. Even a cat on the hunt for a mouse will react intelligently to unexpected events. It will *change* its intention if appropriate (e.g., if a dog appears or the mouse doesn't show). It will *modify* its technique if necessary (e.g., if its hiding place is seen or the mice change their strategies). It will *adapt* its conception of form and of substance (e.g., it will learn to ignore a child trying to fool it with an imitation mouse on a string, and if a bird flies by or a bowl of milk is brought, it will happily turn to the alternative foodstuffs).

In contrast, simulated ("artificial") intelligence can only adequately react to any situation foreseen by the developers: "If the yarn runs out, stop the machine." We do not consider a loom clever for stopping when there is no more yarn; rather, credit goes to its inventor and makers. There are, indeed, so-called "learning programs" for computers by means of which they react increasingly appropriately through experience (e.g., handwriting recognition programs that improve their accuracy each time they are corrected). These are not exceptions to the principle of mechanical reaction any more than a mechanical device for adjusting the loom tension on the basis of the already produced weave would be. The possibilities for recognizing and adjusting are actually static, and truly unpredicted events (e.g., a person writing Chinese, or backwards, or employing an unfamiliar letter—á, ö, ø, π—or putting the wrong document into the machine, or the right one upside down) will always show up the precise limits of the makers' forethought. Note well: We encounter the *makers' intelligence* (and the limits of their forethought), not the intelligence or forethought of the machine; the latter has neither of these.

Faced with any of the difficulties mentioned in the last sentence but one, a human being would discover the nature of the problem and try to find a way to sort it out; a computer can, at best (that is, if it even discovers that there is an unexpected "input"), give some form of response equivalent to: "Unpredicted situation encountered. The limit of the technology has been surpassed. Please call an intelligent being."

For a human being can learn to read Chinese or ask for a translation, to pronounce an unfamiliar letter, and to check if a document is the correct one and oriented properly. A computer can only be re-programmed to do these things.

A computer cannot formulate any sort of conception of Aristotle's ways of experiencing the world: cause, purpose, form, or substance. All that it has are electronic states that we then choose to interpret as being "about" the world.

The extraordinary range of simulated intelligence already and soon to be achieved must not, and indeed cannot, fool us. Computers are unintelligent machines, and anyone who works with such devices quickly discovers that the user's behavior must be made equally unintelligent— that is, we must conform precisely to the machine's severely limited schema. Any activity outside its schema is either ignored or promptly leads to unexpected and normally undesirable results. A computer is completely unable to become aware that it is trapped in a schema of behavior. It is left to the human being to discover this about it, and then to progressively discover the nature, possibilities, and limits of the device's programming.

As they lack all understanding and creativity, these devices can take over only processes that can be translated into a series of automatically followed steps.

When a radio plays music, a child may wonder where the musicians are inside the box. As sophisticated adults, we might smile at the question, for we know that the radio contains no musicians, only a mere reproduction of music. We must be careful not to do something similarly childlike when we are faced with sophisticated modern computing devices. We must learn to look at computers and know that there is no intelligence there, simply a cleverly made recording of intelligence, subject to all the limitations of any recording and, above all, to the limitations of its fashioners.

The Imprint of Intelligence

This raises quite a few questions. How is it possible that even a remotely plausible or momentarily convincing illusion or simulation of intelligence can be produced by a mere array of switching devices? What do we mean by intelligence, if this looks like a case of it? Which aspects of intelligence are present in a computer and which are absent? Finally, what is the ultimate limit of the simulation—how far can it be taken?

A great deal of our thinking has been systematized over the last centuries. The beginnings of this systematization can be traced back to the fourth century BC, when Aristotle formulated rules on how to think logically. This gave thinking a direction toward understanding the material world and its laws and away from the imaginative, pictorial thinking that had previously held sway. By now, having been practiced for two thousand years, Aristotelian logic has been absorbed into humanity's evolution. Who is unfamiliar with causal logic today? Logical thought has accompanied and perhaps even guided the process of incarnation into our physical brains, allowing us to use their workings as a (perhaps largely unconscious) model for the computing devices of the last century.

Today we are masters of many intellectual faculties that were once reserved for a rare few not many centuries ago. Reading, writing, calculating, and logical analysis were rare accomplishments until the Renaissance, and the popular revolutions of the 18th century brought their impulses into universal intellectual education. When we speak of this advance in universal education, however, we should be careful to note that the education of many skills—spinning, weaving, milking, mowing, and reaping, etc.—was nearly universal in earlier days and has been almost completely replaced by the intellectual skills taught in our schools today. There is not necessarily more education today; instead, we have traded education in practical and artistic skills for education in intellectual attainments.

There is good reason for this transformation. Over approximately the last five centuries, through the increasing consciousness of the physical body, it has become possible to create machines that imitate various bodily functions externally. The physical experience of the limbs as mechanical apparatus has led to the development of a wide variety of machinery that works on analogous mechanical principles: for example, digging, hammering, sawing, kneading, weaving, and sewing. These "limb-machines" can be driven by devices that transform energy into usable power through rhythmic action: water wheels, electrical motors, and steam, diesel, and internal combustion engines. Most recently, devices have been developed which record and process information in order to control machines of the first two types. The mechanization of practical work and of power production has considerably reduced the need to educate people in the practical work a society requires.

After mechanizing practical and artistic skills, we are discovering that intellectual achievements, too, are capable of being mechanized by a computer.

Similarly, the reproduction of artistic works has considerably diminished the need for artists. A great many small towns used to have their own opera companies and theaters. If you wished to hear music, you had to find a musician. Skilled artisans duplicated great works of art so that many people could have a reproduction hanging in their houses. Today, factory-produced recordings of music and reproductions of art have replaced an entire culture of middle-level artistic production.

After mechanizing practical and artistic skills, we are beginning to turn our attention to intellectual achievements and discovering that these, too, are capable of being mechanized by a computer. In order to simulate an intellectual skill on a computer, this skill must be reduced to a series of mechanically executable steps. These steps must be capable of being translated into a series of automatic operations on a range of electronically simulated zeros and ones ("off"s and "on"s), though this process is often invisible to the user. This reduction of intellectual work to a series of primitive operations on a series of binary values results in the highly impressive achievements of calculation, presentation, and systematized record keeping with which we are familiar.

The history of computing is thus in part the history of the reduction of intelligent activity to mechanical process. Important to note here is that the mechanization of thinking has often preceded computerization. It was because bookkeeping, for example, had become a rather dull, mechanical activity that Pascal designed the first automatic calculator. Tasks have often become fit for computers (and unfit for human beings) long before they were given over to the machines. To a considerable extent, the activity of computers frees human beings from dreary, repetitive intellectual tasks just as we can be freed from wearying, back-breaking, repetitive mechanical tasks by the practical machinery that surrounds us.

Perhaps it is worth emphasizing one last time, however, that, though a great deal of creative ability and intelligence is devoted to developing the machines in our times, these same human creative abilities and active, penetrative understanding can never be accessible to automatic machinery. As they lack all understanding and creativity, these devices can take over only processes that can be translated into a series of automatically followed steps.

The physical processes of the metabolic-limb, rhythmic, and sense-nervous systems are accompanied by soul processes. Our limb activity is directed by an active will; our rhythmic activity of the circulation of fluids and of air is interwoven with feeling; our nervous system is active as the expression of meaningful thought activity. In the machine, none of these soul qualities is present; it is as if we had before us a being that is just limb movement, without direction, or one that is purely endless rhythmic circulation, without significance, or one that is purely calculation, without understanding. Of course, we can employ these dumb servants for our own purposes, significance, and understanding. Who is it that we are employing here, though? Perhaps at times we will even begin to ask: Who is serving whom?

The Role of Artificial Intelligence in Earth's Evolution

Humanity is becoming increasingly responsible for guiding the evolution of the earth. We already have great power to shape the inorganic world: to build with stone, tunnel under mountains, and create new metals. Huge regions of the earth have been settled and given a physical formation completely determined by human influence: flattened, tarred streets and concrete sidewalks connecting brick, stone, and wood buildings. The plant and animal realms are also coming to an ever-greater extent under human influence and control. Given the alarming rate of human-induced loss of species, on the one hand, and the rapid increase in human-produced hybrid and gene-modified organisms, on the other, it is fair to say that life on this planet is becoming increasingly dependent upon human direction for its evolution. We are becoming the lords of all creation.

Our own health and balance depend upon our maintaining a caring relationship towards the beings of nature.

To care for the natural world is a valid and extremely important part of our task on earth, but one that comes with great responsibility. The difficulty here is to keep the balance between two extremes. One extreme is the wish to deny this task and hand nature over to "itself" (a self that it has not yet developed). This view ignores the fact that human beings are also natural beings, which is to say that in denying a human role in nature we deny part of nature itself. The opposite tendency is to impose our might and will on the lower realms of creation without perceiving or respecting their own nature and character. This attitude ignores the interdependence of all life; to damage nature is to damage the foundation of our own existence. It is our task to find a balance between these extremes, by exercising a respectful yet active guidance over the realms of nature.

A responsible attitude towards nature requires increasing consciousness of the natural world's diversity, rhythms, and interdependencies: in short, its ecology. Unless we respect, preserve, and enhance these, treating them as if nature's beings were our own children, we shall lose the right and the capacity to live in a natural world. Our own health and balance depend upon our maintaining a caring relationship towards the beings of nature.

Humanity's capacity to be true cultivators of the earth remains modest. Thousands of years—epochs and eons—of work and research lie ahead before we shall be able to do full justice to the realms of nature subject to our influence. To understand the full magnitude of the task, it may be helpful to recall how spiritual beings once played a role in establishing the original physical basis for our own entry into evolution on the physical plane.

Our responsibility for the evolution on earth of new beings is analogous to what was once done for us. According to Rudolf Steiner's description, in the diffuse sphere of warmth available as a medium at the moment when the basis for our own physical bodies was laid down, beings of evolution three stages ahead of the human being established forms that would serve as the basis for the evolution of the human physical body. Now, having evolved life forces, a psychology, and self-consciousness, we are coming to be responsible for the evolution of other beings, even for helping to form physical bodies from which new evolutions may develop. In our work with the mineral realm, three levels of existence below our own evolution, humanity has an analogous task to the role of the Spirits of Personality in the formation of our own physical body. The mineral world is today in the state of development that human beings were once in their earliest stage of unfolding. We now have the task of taking the material substance of the earth and giving it new forms, into which new beings waiting to incarnate have the chance to enter the stream of evolution.

We are now using intelligence to fashion the mineral world into many forms and structures, and either permeating these with a harmonizing aesthetic and higher purpose—or neglecting them.

This process can take various directions. We can picture, for instance, the awesome transformation involved in reshaping masses of incoherent rock into the magnificence of a Chartres Cathedral. According to Steiner, during the phase of earth's evolution that will follow our own, a work such as Chartres will arise in metamorphosed form. Such artistic creations will appear in a next cycle of evolution as flowers appear during our phase of evolution, that is, equipped with life forces and capable of growth and decay, though with a mineral body. New life forces capable of enlivening a body of stone will permeate their transformed existence. I visualize magnificent flower-like organisms with crystalline blossoms, a more stone-like leaf and stem region and then truly stony roots. Imagine such a transformation of Chartres Cathedral, the Parthenon, Hagia Sophia, or the first Goetheanum.

Other physical structures that human beings have created will also provide paths of incarnation for beings. In particular, let us turn to computers. Computers are fashioned by shaping mineral substance—crystals (usually of silicon) and conductive metals—into incredibly complex and finely fashioned patterns of electronic circuitry. These transformations of the mineral realm are an expression of something fundamentally different from exquisite works of architecture. Architectural works are always a combination of the practical will, aesthetic feeling, and the insightful mind—elements the Roman architect Vitruvius called structure, beauty, and function. The design of computer circuits is usually not much influenced by aesthetic considerations and its intended functions no longer include the full range of human life. Computer circuitry is purely determined by the rational intellect's logic working at refinement and complexity, but also at a merciless absoluteness of principle previously unknown in world evolution. An automobile engine, otherwise a triumph of modern precision engineering, is but a child's toy, in comparison.

What beings will find a path to incarnation through these formations, both now and in future planetary phases? Following Steiner, I have suggested that the wondrously complex harmony of Chartres can be imagined as being transformed in a future evolutionary phase into a flower having all the lovely, wonderfully complex harmony of the cathedral, yet being equipped with life—a mineral form, in other words, capable of growth and decay. When we come to the integrated chip, the computer, I imagine a living, growing being with the laws of these devices as its basis: a one-sided, virtually parasitic virus of the future earth. Incapable of existence except by feeding on beings of more well-rounded capacities, these will have only one purpose: to reproduce themselves and extend their crystalline maze of logic over all of the earth.

The universe we live in was formed out of wisdom, through the logos. The microcosmic correspondence to this cosmic wisdom is our human intelligence, which has evolved through the successive stages described above until it has reached the level of understanding applicable to the physical world. Because human intelligence is an image of cosmic wisdom, human understanding can comprehend the universe's laws, rhythms, and workings. We are now using this intelligence to fashion the mineral world into many forms and structures, and while doing so either permeating these with a harmonizing aesthetic and higher purpose—or neglecting them.

But our universe was not meant to be—and has not remained—solely an expression of wisdom. The principles of freedom and love have entered into human—and thus also into the world's—evolution. Through us, the kingdoms of nature can become imbued with love. We can shape the mineral world into forms literally built out of love, not simply dictated by the intellect or the will to power. The plant world, if cultivated with love, will evolve in different directions than it will if we impose a mineralized, rationalized farming upon it. The animal world, nurtured with love, will find through us new possibilities of evolution that will be supportive of and in harmony with humanity's activities and needs.

The principles of love and freedom must enter into all of our life and deeds—and especially into our formative activity with nature. The critical question accompanying the evolution of artificial intelligence, then, is this: How do we imbue these constructions with the new principle of love? Is this even possible? The electronic mechanisms we make will certainly carry over into future generations the outer image of the workings of earthly intelligence, of the intellect. This is surely part of their task: to carry out for human beings the repetitive functions of earthly intellect, not least in order that humanity is freed to move forward beyond this state, to remount the steps of intelligence's fall through our own conscious and purposeful activity. How we shape these beings' physical form is of vital importance to how this task will be carried forward.

Machines can lead us further down the path towards the mechanization of our own intelligence, or they can free our intelligence from a focus on mechanical tasks so that it can find its way back to its cosmic inheritance.

Machines can be created and used in a way that leads us further down the path toward the mechanization of our own intelligence or they can be used to free our intelligence from a focus on mechanical tasks so that it can find its way back to its cosmic inheritance. We are imprinting our intellectual achievements upon the lowest realm accessible to us, the mineral world. But in doing so we face the danger of being confronted everywhere by the outer form, the hardened shell, the husk of intellect in the very world we fashion for ourselves. Only if we truly understand what we are doing here will we find the proper place for this synthetic intellect and preserve a space for the human qualities of engaged will, active love, and living intelligence.

Artificial intelligence, as we meet it in computers, confronts us with two challenges. One is that human intelligence will fall under the spell of mechanization rather than guiding it. Creators of mechanized technologies often fail to comprehend the effect of these technologies upon the human life of soul and spirit, including their own. At the other end of the spectrum, those who may be most concerned with this effect are often unable to fully understand the technology itself. To bring an increased comprehension of both the technology and the soul and spirit realities that underlie our relationship to it is our first challenge.

The second challenge is this: Even if human beings preserve a healthy soul life despite their increasing contact with computers, how are we to relate to the beings that are incarnating into the world through this technology? In a sense there is one being who underlies all computer technology, incarnating in a manifold of individual devices. What vessels for incarnation are we creating? Here is a task that we will carry forth over eons of world evolution: both to care for the world into which we are introducing a new and in many ways potentially detrimental element, while at the same time caring for the future development of this being in its many guises.

Love is active knowledge, and without real understanding there can be no love. If we can awaken in ourselves a real understanding of the nature of the beings we are working with here and of their mission, and if we can face these beings not just with understanding, but also with real compassion for their nature and mission, then we will be able to find ways to redeem them. If those who create new forms in this realm become capable of real understanding, knowledge, and perception of what it is that they are creating, and in the face of this develop this love and compassion, then we will be able to look forward to the future with a degree of confidence.

Beings of pure logic will be with us in the future. They will incarnate into the forms that we are making available for them. But human love and the will to redeem these beings through the forces and insight developed out of an unsentimental recognition of and compassion for them may also be there in sufficient force. Upon this depends our future—and not ours alone. The whole earth's evolution depends upon our insightful love and compassionate will.

Conclusion

I opened this essay with the question: What intelligence do computers exhibit? I then sought to justify the following response: A computer presents us with a dead image of intelligence, a reflection in a mirror that human beings have erected. Artificial intelligence is an empty form, a barren shell; it is intelligence's shadow, without intelligence's light.

Looking at our creation, we see our own reflection, our own intelligence, in the polished mirror we have made, and we may almost see the reflection before us to be itself imbued with life, with its own intelligence. We can breathe life into this mirror for moments, but as soon as a human being steps away from the devices, they return to being empty mechanisms. Computers may present the outward form of intelligence but they lack its inner reality.

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Technology and the Laws of Thought
Part 2

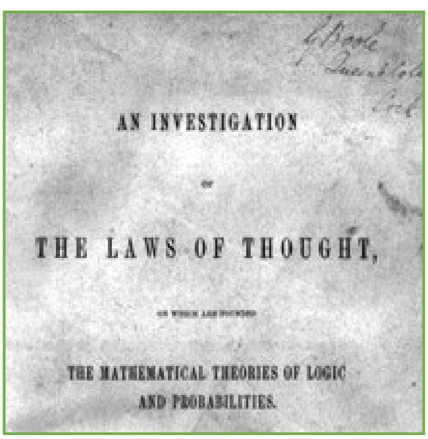
Gopi Krishna Vijaya

The Laws of Thought

> *No matter how correct a mathematical theorem may appear to be, one ought never to be satisfied that there was not something imperfect about it until it also gives the impression of being beautiful.*
>
> – George Boole

The dawn of the 19th century saw a rapid development of natural science, leading to the rise of new ideas in physics and mathematics. Industries were in full swing, laws of electricity and magnetism began to be investigated (by the likes of Faraday, Volta, and Ampere), and non-Euclidean geometry was developed by many mathematicians, including the "Prince of Mathematics," Carl Gauss. Devotion to architecture of buildings was now transferred either to technology or to a study of the architecture of the human body, leading to large strides in anatomy and physiology. Cell theory took shape, and the possibility of different functions of the body being localized in different parts of the brain began to be investigated.

It was precisely in the midst of this environment that George Boole (1815–1864) lived, and his life shows the indications of the struggle between the different aspects of the thinking process. Deeply religious by nature, Boole had a mystical experience in 1833, later described by his wife, Mary Everest Boole:


AN INVESTIGATION

THE LAWS OF THOUGHT,

THE MATHEMATICAL THEORIES OF LOGIC AND PROBABILITIES.

> My husband told me that when he was a lad of seventeen a thought struck him suddenly, which became the foundation of all his future discoveries. It was a flash of psychological insight into the conditions under which a mind most readily accumulates knowledge [...] For a few years he supposed himself to be convinced of the truth of the Bible as a whole, and even intended to take orders as a clergyman of the English Church. But by the help of a learned Jew in Lincoln, he found out the true nature of the discovery which had dawned on him. This was that man's mind works by means of some mechanism which functions normally towards Monism. (M.E. Boole, *Indian Thought and Western Science in the Nineteenth Century*, 1931)

The inspiration for inner effort is once more seen to originate in the sphere of religion, as borne out by Boole's deep interest in all religions and his desire to work in the cause of "pure religion." Studying his life and conceptual development must hence necessarily include the logical precision, the aesthetic sense, as well as religious devotion simultaneously, as it existed in the individual. This is not usually done today, and there is a recurring tendency to pick and choose. Only one part of the story is valued and the rest discarded as being irrelevant (quite against the spirit of scientific investigation):

> The father of pure mathematics, as Bertrand Russell would later refer to Boole, had not

> been purely interested in mathematics, nor was his mathematics free of the "impurities" of extradisciplinary concerns, in particular, religious ones. The symbolic logic that is now the essential tool for secular philosophers and that forms the basis for dispassionate computers began in the mind of a warm-blooded, religiously concerned idealist. (Dan Cohen, *Equations from God*, Ch. 3, 2007)

In other words, the assumption is made that mathematics is "disciplinary" and everything else is necessarily a separate box or an "impurity." This assumption is one of the primary reasons why this aspect of Boole's life and work is hardly known or even realized today, making it a fact worthy of mention.

As already described in Part 1 of this series (*Research Bulletin* 21-2, Autumn/Winter 2016), Bacon pioneered the use of binary to represent letters and language. Leibniz developed the use of binary numbers in mathematics and suggested their use in calculating machines; he also suggested that logic might be represented mathematically. Boole took the first steps to accomplish that by trying to represent thought and logic itself in a binary form. Language, Mathematics, and Logic—these were the domains that could now be represented in a binary form, as a work of the Philosophers. It is clear that there are a finite number of letters in the alphabet, and a finite representation of numbers. Thus, letters and numbers can be represented in binary, a feat which does not alter the very content of thought itself. For instance, I can express a number in any base, and I can also write a certain word in any script. The form of the letter is not crucial to understanding the meaning of the communication. However, with Boole, the notion of "meaning" and logical thinking itself is expressed in the form of binary algebra, which has to be analyzed further.

Boole considered his work a natural extension of the works of Aristotle. Prior to Boole's analyses, logic was developed as an interrelationship of concepts or propositions, which were then differentiated. Qualifiers such as "all objects," "some objects," and "no objects" were referred to as *subjects*, while their qualities, e.g., "round," "white," etc., are called *predicates*. The verb forms the link or *copula*. The copula was seen as a logical connecting link, and it is normally a verb. In other words, the bridge between the subject and predicate involved either an existence (*is*) or lack of existence (*is not*). Together, different kinds of propositions were created, such as:

All diamonds are solid.
Some stones are soft.
Some pebbles are not black.
No rocks are liquid.

Logical propositions were studied, discussed, debated and elaborated by the Greeks of the same period, the Arabs of the 7th–10th centuries, and the Scholastics of the 13th century. Thus, the works of Aristotle on logic have had an immense role in the development of further thought for nearly two millennia. Nevertheless, the development of a logical train of thought itself was not altered, and everything was still expressible in terms of basic syllogisms such as this one:

All diamonds are solid.
Kohinoor is a diamond.
∴ Kohinoor is solid.

This is essentially the crux of the development of logic, and is also called a *syllogism* or *deduction*. A logical deduction was therefore at the root of all philosophy for many centuries, as workers in this field strove to build thought itself and also the relationship between man and the world. Rules were derived for these logical deductions and for determining validity and invalidity of propositions. The laws of thought according to this system are:

A is A
Law of Identity: A concept is equal to itself.

A is not (not A)
Law of non-contradiction: A concept is not the same as its opposite.

All A is either A or is not A
Law of excluded middle: A concept is either true or false.

These were followed quite strictly by medieval logicians. For example, Avicenna (10th century) is said to have declared that: "Anyone who denies the law of non-contradiction should be beaten and burned until he admits that to be beaten is not the same as not to be beaten, and to be burned is not the same as not to be burned." A dry sense of humor indeed, but it is hard to imagine today how central these debates were to the intellectual life of the time, when the ideas one held to be true had life-or-death repercussions.

It can be seen in the form of the copula that the laws of logic denote *static* situations, i.e., either something *is* or *is not*. There is no other possibility. It is interesting to probe the origins of these statements in logic and ask why the Greeks posed a statement in that particular fashion. Because the experience of one era determines the concepts woven out in the following period, the natural question to ask is: What motivated the laws of thought? What was the experience on which these laws were based?

A study of the thought life and pursuit of Truth of the ancient Greeks shows that geometry was revered, as was music (*Harmony of the Spheres*). It was understood that in geometry man could really grasp the structure of the world and man's place within it. This is indicated by the Platonic saying "God geometrizes" which was said to be written at the entrance of his School of Athens. In fact, Aristotle was a student of this school himself, and geometry formed the soil for the seeds of logic to be sown. For example, a shape is either a triangle or not a triangle: The same spatial experience could not take two separate forms at the same time. A triangle as a concept remained something static and did not change with time, giving an assurance of a firm foundation for thinking. This clarity of thought in geometry guided the early development of logic as well, resulting in a twofold copula: *is* or *is not*. The origin of the copula can be indicated as:

School of Athens =>
Geometry =>
Copula: *is*/*is not*.

Similarly, it can be observed that there are *quantifiers* in the statements: *all, some,* and *none*. Here, it is a matter of encompassing the element through number, which is necessarily what our notions of quantity are tied to. Whether or not an actual count is performed, *all* is necessarily more encompassing than *some*, and *some* is more encompassing than *none*. The origin of these relationships can be traced to the domain of arithmetic, or the positive real line. This was the development that had its roots in musical ratios and numbers. It is important to keep in mind that it is the form of the quantifier itself that is of interest here, and not the concept that it is referring to. For example, consider:

All ideas are wonderful.

It is not important whether or not the *ideas* are quantities, but that the notion of *all* itself is derived from the notion of a quantity. Quantities owe their origin to arithmetic. The origin of the laws of arithmetic can be traced back to a much earlier School: the Pythagorean. The Pythagoreans revered numbers above all as the guiding principles of the Universe, and their ideas had taken strong root by the time of Plato and the School of Athens. Geometry was also seen as being derived *from* arithmetic, paralleling their natural developments in the Schools of Pythagoras and Plato. Hence, the derivation of logical terms is:

School of Pythagoras =>
Arithmetic =>
Quantifier: *all/some/none*

School of Athens =>
Geometry =>
Copula: *is/is not*

It is well known that the Greeks were quite skilled in the development of both, and it comes as no surprise that logic owes its origins and internal structure to ideas from geometry and arithmetic.

There is yet another aspect of this logic that has to be addressed. This is the *subject and predicate*, which can be called *class* in general. Conventional understanding simply takes *class* as "collection of objects" or a sack of goods, plainly speaking. However, meanings for the same words can be quite different in different periods (an early example is perspective drawing). Hence, this does not take into account that in the Greek era, even ideas were treated as real "objects." Indeed, Plato's philosophical work involved the notion that true reality consists of ideas. In stark opposition to Plato, the Stoics of a later era considered the entire world including ideas as being corporeal, or physical. This also mirrored the different motivations of Platonists and Stoics: Platonists were concerned with concepts from the ideal world (metaphysical realities), while the Stoics focused on actual application within a deterministic physical world.

These polar opposites must be taken into account, as they are central to the operations of logic that developed later. If the name of a class of object or ideas is called "concept," the summary of Aristotelian logical forms can be written as:

Quantifiers: Arithmetic
Copulas: Geometry
Class: Concepts (objects/ideas)

The Stoics were more interested in the utility of the laws of thought to living a moral life than in deriving implications of the laws themselves. This meant that they focused on the class alone, and developed consequences. Naturally, Aristotelian logic involved these derivations of consequences, but they were not studied exclusively as done by the Stoics. It is therefore from the Stoics that sentences of this form are derived:

If A then B
Not both A and B

This is perfectly suited not only to develop consequences, but to determine actions. A and B can thus denote *actions*, in addition to ideas or objects. It also rests on a condition "if," which separates the true from the false, the "is" from the "is not." Since A and B can denote actions, the following statement is also possible.

If A then *do* B.

This then adds to the list of copulas, in a different form—not only can B *exist* or *not exist*, be true or false, but it can also be *done*. It is particularly well suited to applications. The updated summary becomes:

Quantifiers: Arithmetic
Copulas: Geometry (is/is not), *Actions (do)*
Class: Concepts (physical/metaphysical)

This brings the discussion from the realm of the Philosopher back to the realm of the Craftsman, and it is worthwhile to see that the logic of the Greeks had its renaissance only in the 19th century: the age of the Engineer/Scientist. In this era, Boole developed a logic that expressed only one particular form of the four Aristotelian copulas, viz., *equality*, represented by *equations*. The four statements of the Greeks are reduced to one expression relating to concepts.

All diamonds are solid. 1
Some stones are soft. 2

Some pebbles are not black. 3
No rocks are liquid. 4
=> Coal = Black

Since equations with variables are nothing but the formulation of *algebra*, for the first time logic is expressed through algebra, a branch of mathematics. Logic gets mathematized for the first time. This conversion of logical copulas to equality has been addressed in recent works:

> Where Aristotle saw predications, Boole saw equations. Boole realized that his theory of logical form was in radical opposition to Aristotle's, but he seems to have thought that Aristotle had just not gone deep enough, not that Aristotle was fundamentally mistaken. Boole's pattern was S–is–P, Subject–is–Predicate, or S=P, Subject equals Predicate. (Corcoran, THPL 24 p.261, 2003)

This conversion of four possible expressions into the single expression of equality had its consequences: What was immediate for Aristotle required mediation for Boole. Again, Aristotelian simplicity becomes Boolean complexity. For example, Aristotle would go from the two premises "Every square is a rectangle" and "Every rectangle is a polygon" immediately—in one step—to the conclusion "Every square is a polygon." Boole broke this down into eight tediously meticulous equational steps. The first step is going from the second premise, "Every rectangle is a polygon" to an intermediate conclusion arrived at by something analogous to multiplying equals by equals, namely "Every square that is a rectangle is a square that is a polygon," "multiplying" both sides of the equation by "square." (Corcoran, ibid.)

In other words, conversion of all the copulas into a single one (*is* or *equals*) made the representation of statements cumbersome. If only *equality* is included as a copula, there is naturally no inequality that can be expressed, leading to the complications just quoted. If Boole wanted to *extend* logic, a natural way forward would have been to study different copulas, which do not make sense in Aristotelian formulation. For example, compare these two sets of statements:

All men are mortal.	All children like candy.
Socrates is a man.	The cat likes children.
=> Socrates is mortal.	=>The cat likes candy.

The second syllogism on the right is not necessarily valid in real life, and it indicates that a different domain opens up when a different copula is used. Hence, a new form of logic can be determined for *likes* and *does not like* just as it was built up for *is* and *is not*. Instead, the set of copulas is reduced to just *is* by Boole.

This alteration had other effects as well. With the nature of the copula altered, the subjects, predicates and quantifiers changed. Boole reduced the quantifiers *all, some*, and *none* to just two: *all* (1) and *none* (0). Also the quantity, which stood by itself in the traditional system, was now inserted *with the class*. This means that one no longer had *all diamonds* but instead just a single *all-diamonds*, which became the same as just diamonds because *all* = 1. Similarly, instead of saying "*no* diamonds" one had to say "*no* all-diamonds." The quantifier gets attached to the class itself. Hence, just as the ancients had to create a number to represent zero, for the first time a new *class* or object also had to be created for the purpose of saying "nothing." Nothing becomes a class of objects! For example, the standard logical statement transforms like this:

No A is B.
∴ (*No* A) is (B).
∴ (All A) and (All B) is (nothing).
∴ A.B = 0

This is a phenomenal transformation, as the variable "zero" or "nothing" has literally been created *ex nihilo* to fill in the function of *is not*. Because the copula is no longer available, the object itself must have "nothing."

These laws developed by Boole were complemented and enlarged by Gottlob Frege (1848–1925). Like the Stoics before him, Frege concentrated on creating a system where all logical statements can be expressed symbolically, and also applied. Hence, he elaborated propositional logic in a mathematical form, making it possible not only to express equations mathematically, but also to include the application using propositional statements (*if… then, and, or,* etc.). This enabled logic to be expressed as a *mechanism,* an *action*. What Boole did for Aristotle, Frege accomplished for the Stoics, and the works of these two thinkers and their contemporaries (such as C.S. Peirce) form the basis of what is known as Boolean algebra today.

If all the quantifiers of traditional logic had been included, it would never have been possible to indicate it by a machine, because of the quantifier *ALL.* As hinted earlier, these quantifiers bear a direct resemblance to arithmetic, represented like this:

NONE	0
SOME	1
ALL	∞

No mechanism can generate infinity, so that had to be removed. The meaning of *ALL* is shifted onto "1," giving:

NONE	0
ALL	1

The quantifier *SOME* is no longer required: It is simply absorbed in the class name itself. Therefore, both the names of classes (subject/predicate) as well as the copula (*is not*) become *quantified*. This conversion of all logical statements into algebraic form is thus seen to remove everything that could not be quantified or mechanized and retain only that which could. It is not an extension, as Boole believed, but a reduction, a filtration.

Reductions of logical statements into mathematical expressions make them well suited to include both calculations and the rules of calculations into the mechanism of a device. Sure enough, this generated the possibility of replacing the will element of thinking and to outsource it to the machines:

> With earlier sorts of logic, to determine whether the validity of an argument had been proved, we still needed to understand the meanings of words—at least *some* of the words—and this meant we still need to *think*. With symbolic logic, by contrast, we don't need to think at all, or rather the only thing we need to think about is whether the symbols appear in the order specified by the rules that govern them. In consequence, so long as the proof is sufficiently spelled out in a symbolic language, the task of verifying it is strictly clerical. What we look at is simply a matter of form—and *purely* form. … In this respect, then, determining whether an argument's validity has been proved within the system is strictly mechanical, and, in our age, it can certainly be done by machines. (Shenefelt and White, *If A then B, How Logic Shaped the World*, p.252, 2013)

Thus, "formal" logic served to reduce the necessity for thought and to increase the mechanization of concepts.

At this point, it is worth asking: Was this "mathematization" necessary? In other words, what prior reason could one have to insist that logic has to be mathematical and, more specifically, algebraic? What is the reasoning that motivated this logical development? A study of Boole's works gives a surprising answer to this:

> Whence it is that the ultimate laws of Logic are mathematical in their form; why they are, except in a single point, identical with the general laws of Number; and why in that particular point they differ;—are questions

> upon which it might not be very remote from presumption to endeavor to pronounce a positive judgment. Probably they lie beyond the reach of our limited faculties. (Boole, *Laws of Thought*, Ch.1)

Thus, there is no specific reason for insisting that logical rules have to correspond to mathematics, other than the general feeling of confidence that thinkers have in the methods of mathematics (perhaps due to the great success of the Industrial Revolution) as exemplified by Boole. It is a *claim* and not a deduction from previous circumstances nor a solution to a specific problem. This fact is important to highlight as it shows that the factors motivating the *creation* of mathematical logic were *neither mathematics nor logic*.

Boolean algebra connected logic to algebra, in the process significantly altering the form of logic as it was practiced for centuries. Several features of logic were extended, but only in terms of their algebraic representations (logical gates such as AND, OR, NOT, etc.) At the same time, quantifiers are reduced from three to two, copulas are reduced from two to one, and new categories of "everything" (1) and "nothing" (0) are introduced as classes. Language and verbal influences are removed entirely and replaced by abstract symbols. Thus, while the theory itself was generated due to the *religious* will-temperament of its creator, the effect of it was to create *mechanical* (will) equivalents of logical statements. *Religious* will inspired *mechanical* will.

Traditional logic was guided by geometry and arithmetic, which were in turn guided by experience. Replacing this by an "algebra" of logic removes those restrictions of experience, giving it a free reign in terms of equations and combinations. Hence, Boolean algebra *appears* to show an extension of logic, even though it is a reduction of it to include only a subset of mathematical concepts.

Mathematics is logical. But now, since logic and algebra were combined as symbolic logic, this form of logic had an effect in turn on mathematics itself. Hence, mathematics itself is changed and seen differently. Because mathematics is at the core of science, this impacted all of natural science.

Numbers and Neurons

> *Music is the pleasure the human mind experiences from counting without being aware that it is counting.*
> – Gottfried Leibniz

So far, the transformations occurring in logic and their relationship to mathematics have been described. In particular, the key changes that occurred with Boolean algebra have been indicated, viz., the transformation of the quantifier "all" from infinity to one, the removal of the copula "is not," and the addition of the concept "nothing" into the predicate or class name. Frege's work helped to make this logic practical by retaining the copula "do" and expressing a logical statement as a sequence of abstract operations. That which earlier required a knowledge of language, and hence an evaluation of meaning, was converted into an automatic operation. In addition, the sequence of development of logic was now reversed:

Mathematics and Arithmetic =>
Geometrical understanding =>
Logic of Ancient Greek (ca 200 BC)

Logic of Ancient Greek =>
Algebraic expressions =>
Mechanical operations (ca 1900 AD)

In other words, instead of deriving logic *from* mathematical understanding, it was *equated* to a specific mathematical domain. This logic, called *symbolic logic*, now became identical with mathematics. It is but natural to go one step further, and that is precisely what happened: A new mathematics was derived from symbolic logic. Development of mathematics hence came full circle, from mathematics generating logic to symbolic logic generating formal mathematics.

Mathematics =>
Greek Logic =>
Algebraic Logic =>
Formal Mathematics (200 BC to 1900 AD)

As indicated earlier, while engaging the thinking process, there is a direct perception of a force, or will element, in the effort needed to form a thought. Without this will element, there is no difference in thinking about something for the first time and thinking about something that has already been thought about. It has also been indicated that only the repetitive aspect of this force can be directed to a machine. An example can be used to study this process in some more detail.

Assume that you are asked to derive the surface area of a cone for the first time. The first struggle will probably be the hardest, as you wend your way using calculus to determine the right formula. Now, if the same question is given again, and you are asked to demonstrate to a third party, the derivation flows more smoothly, and the effort involved is significantly less. After a few repetitions, there is minimal effort involved, and the process becomes automatic and, as a consequence, easier to repeat. Compare this to the effort involved in lifting, say, a heavy rock. The first time, there is a large effort involved. After several repetitions, involving perhaps weeks, months or even *years* of experience, it gets easier to lift. In the process, both the bones and the muscles are strengthened. Thus, mental effort appears to be a greatly accelerated analog of physical effort. Both have the quality that, with repetition, inner strength increases so as eventually to match the resistance. Once the strengths are matched, the task becomes easier and, in the end, becomes mechanical. Thus, mechanical process is seen to be the very minimal residual form of inner effort.

Secondly, after receiving the problem of a cone, assume that you are given a problem in properties of prime numbers. Naturally, this would refresh the will-element once again. After solving this second problem, suppose you declare that it took the same amount of effort to solve this problem as it took to solve the one on surface area. Nevertheless, doing the problem of surface area again would not involve the same effort, but doing a *new* problem requires roughly the same effort. This clarifies the process some more: *Novelty* is the key criterion that demands effort each time, while *identical repetition* reduces effort over time. Therefore, in terms of the thinking process as a whole, including these willing and feeling aspects, the capacity to understand involves the capacity to generate new ideas, as opposed to repeating existing ideas. This freshness of thinking is developed when trying to understand topics that are as different from each other as possible or when generating new ideas for the same topic.

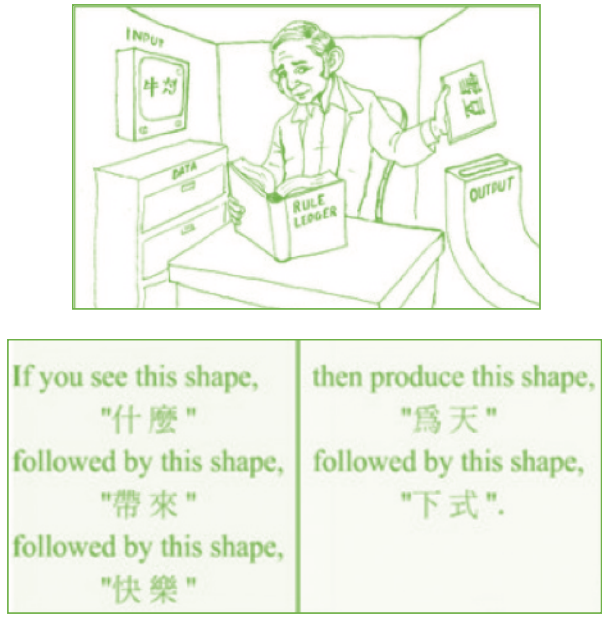
Hence, a healthy thought process necessarily involves creating new ideas. But what is the result of ideas being restricted to those that are logical, algebraic, and, hence, mechanical? The natural consequence of that restriction is that ideas themselves are seen as being mechanisms! In a direct inheritance of Stoic philosophy, whose *assumption* was that the whole world is corporeal, thoughts are seen as mechanisms. Here it is easy to observe how the cause and effect are inverted. The idea of mechanism is one arrived at through many centuries of effort of both Craftsmen and Philosophers, and now it is claimed that thought is a mechanism. It is easy to see how one gets into a knot when pursuing the topic like this, when one asks, “What is a mechanism?” Answering this would require thinking once more, looping back to square one. This is reminiscent of the old joke:

> *What is mind?* Does it matter?
> *What is matter?* Oh, never mind!

An illustration of the fact that mechanism is not the same as understanding a concept is shown by the “Chinese Room Argument,” described by John Searle in 1980.

In this argument, a person who has does not know the Chinese language is kept in an enclosed room and asked to read off a certain set of characters on the input screen. He is given a big, fat rule book, containing all the rules about what the output is for any specific input character set. It is possible for this Translator to generate a response for any string of shapes, and, except for the fact that it would take him a while to provide the response, it would be indistinguishable from someone who knows Chinese. Yet, in spite of the fact that he performs accurate pattern recognition, the Translator knows no Chinese and does not understand what any word means at the end of the day. Meaning is completely missing, as the pattern is *not* the *meaning*. This method of functioning is also seen historically with the first major computing machines: looms that wove patterns of cloth.

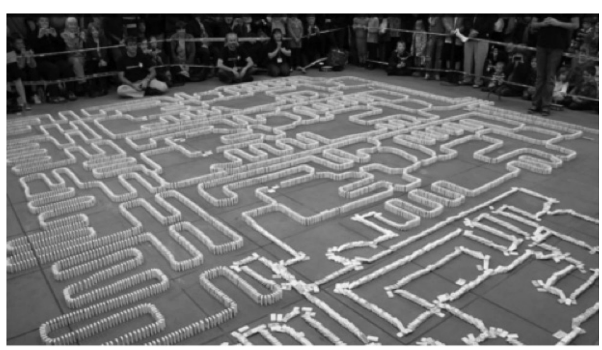
This is a direct result of the application of Frege’s rules for generating symbolic logic, which can be executed mechanically. As a matter of fact, instead of keeping an actual person inside the box, it is possible to replace it with an elaborate pattern of dominoes. All that would be required for repeated operation is that a fallen domino (or



Translator in the room, with his translator (Illustration courtesy: David L. Anderson, CCSI)

sets of fallen dominoes) can be made to stand again by pressing a lever outside the room, or by a falling domino inside the room. In this case, the “rules” are formed by the pattern in which the dominoes fall. By connecting each Chinese character to a specific set of dominoes, which either fall or do not fall, it is possible to generate a response at the output that once more corresponds to a specific character. As anyone who has arranged dominoes for entertainment knows, kicking a domino can hardly be called “thinking.”

Whether it is with dominoes or with gears and levers, the nature of mechanism is clearly seen as something that is necessarily



(Courtesy: Matt Parker’s Domino demo)

deterministic and finite. The placement of the thinking process is also not clearly identified in the case of a mechanical device. Normally it is taken for granted that the machine helps to think once it is set into operation. This idea was suggested earlier, that the repetitive element of thinking might be outsourced to the machine. In reality, the situation is exactly reverse: Thinking is involved only in setting up the "rules" of the operation or in preparing the rule book or the domino arrangement—and it stops the moment the machine is set in motion. Whether one sees dominos falling, gears churning, or electricity firing, the process is identical in essence. It is just like kicking a stone downhill and watching its progress according to gravity. Hence, the basic process underlying computation is mechanism and not thought.

Another consequence of this restriction of logical form to mechanism, especially with the copula and quantifiers, is the effect on the notion of infinity. As already pointed out, geometry motivated the copula, and arithmetic motivated the quantifiers in Greek logic. However, several changes occurred in these subjects toward the middle of the 19th century, simultaneous with the works of Boole. Just a year prior to Boole's *Laws of Thought*, William Hamilton discovered the algebra of quaternions (with one real and three complex quantities).

This topic was added to the already existent serious debates among mathematicians as to the nature of numbers, particularly negative and complex numbers, which could not be grasped intuitively. Hence, as algebra was undergoing a massive change, geometry was also being revamped from the ground up: The Euclidean system that had stood for two millennia, just like logic, was called into question. The postulate that states that parallel lines never meet was found to be unnecessary for a consistent geometry, throwing open the door to Non-Euclidean Geometry and Synthetic Geometry (also called Projective Geometry) that began to be developed as generalizations of Euclidean Geometry. In this form of Geometry, parallel lines do meet—at a point at infinity.

Frege was strictly against the replacing of the axioms of Euclid and, instead, added *more* axioms to make the system stricter. He declared that "no man can serve two masters," i.e., either Euclidean or non-Euclidean systems were true (*On Euclidean Geometry*, p.251, 1997.) Since the assumptions taken to be "self-evident truths" were no longer valid, the reaction was to abandon the idea and focus on setting up a set of abstract axioms, whose consequences were explored.

Around the same time of Frege's work (1879), irrational numbers were clearly defined by Richard Dedekind (1872), while Georg Cantor explored the fact that there are an infinite number of possible infinities (1874). However, the mathematization of logic was restricted to the Euclidean domain, giving rise to analog machines. Moreover, only whole numbers (zero and positive integers) could be represented in binary code, which led the way to digital machines. These were two immediate consequences of the rejection of both projective geometry and infinity–a fact that will be described more in the next chapter.

While infinity is not accessible to mathematical representation, one can still express it as a concept, as it is done in this very sentence. Hence, the logical domain extends beyond that of finite numbers. It is necessary to see that logic is also not restricted by the use of copulas *is* and *is not*. This opens the door to include non-mathematical ideas (or at least, the non-Euclidean) into logical form and to alter the form of analyzing the possibilities in a situation. Hence, thinking has a range that intrinsically exceeds that of mathematics and mechanics.

This fact is mostly overlooked by most comparisons of the mind and the machine. Consider one of the typical examples used for estimating the power of mind and machine: a game of chess. This game has highlighted the epitome of intellectual capacity for several

McGonagall's giant chess set

centuries. It is possibly one of the few games today that is simple and yet represents so well strategy, combinatorics, even elegance and intuition.

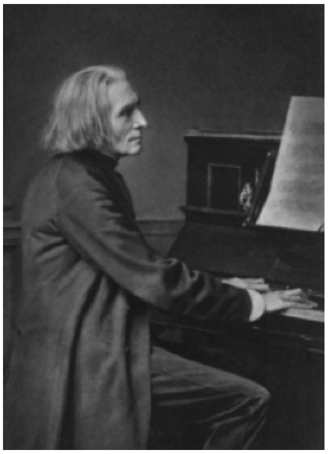
Traditionally, in order to investigate whether or not the machine can compete with the human mind, the number of possible moves is calculated and probabilities weighed in order to determine outcomes. Orderly to begin with, a rough estimate of possible games that can ever be played on the chessboard rises astronomically with every move: 400 board configurations after the first move, nearly 200,000 after the second move, up to 121 million after the third, and estimated to be nearly 10^{100000} in total (no precise calculations exist). This is just with 64 squares and 32 pieces. Because this appears to be a very large, yet finite number, it is likely that inevitably, with the rise in the sheer computing power of machines, a machine might beat a human player. This is the method followed when comparing the mind and the machine: The possible number of combinations is calculated in each case.

However, a second look at the game reveals an inherent assumption in this calculation: *that the rules of the game remain fixed*. Because all the rules are geometrical/arithmetic rules (directions and steps of movement) that can be quantified with just an array of integers, the logic used is precisely that which can be mechanized. What if, instead of restricting logic the way it is usually done, the numbers of possible rule-configurations are calculated? If rules are allowed to change, how would it alter the situation? In this case, one can easily see that the calculations are quite impossible to do, simply because there is *infinity* of rules to choose from. Just as young children make up rules and change them as they play along, rules can always be altered. This option opens the door to the full range of human mental capacities to act and removes the barrier that existed for the "rules of the game." It does not matter if there are 64 squares and 32 pieces or 64 squares and 31 pieces—an infinite number of games is possible if the rules can be changed. As Georg Cantor rightly pointed out, there are an infinite number of infinite numbers. Regardless of the number of squares or pieces, "the sky is the limit."

With just 26 letters of the alphabet, the English language has been growing and continues to grow with every added speaker. Countless numbers of books have been written, poems composed, reports described, with no end in sight. With a few notes of the musical scale, music is still being composed afresh every day. With a few colors, new paintings are created every day. Creativity, therefore, is not limited by the tools of expression or number, but only by the capacities of the thinking and intuitive processes. In numerical terms, a sustained creativity occurs *ex nihilo, infinitum*.

This capacity of the rules to change completely alters the way in which calculations are done and ends up making the calculations irrelevant. As long as the rules for calculations are constant, they can carry some meaning, but what meaning can be obtained when the rules themselves get changed? This explains the difficulty faced by the best of mathematicians when dealing with things like negative numbers and imaginary numbers, because the rules of mathematics are changed.

This possibility of changing rules was missed almost completely by logicians of the 19th century. It is possible that many aspects can now be seen much better in hindsight due to greater familiarity with the nature of technology, while logicians and mathematicians of the 19th century were still experiencing the beginning of the Industrial Age. Biology had already reached a high level of development at the end of the 19th century, with the detailed study of cell structures and the nervous system being conducted. With the advent of technology, cells were seen as tiny machines or tiny test tubes with chemical interchanges with the DNA. The brain itself, made up of neurons, was seen in a similar fashion to resemble a gigantic factory-like operations-control center. Biology was explored using the tools of physics and chemistry, where mechanism reigned supreme, and it began to be taken for granted that cell functions determined human behavior.



Removing the restrictions of number gives a much clearer look at the activity of the brain. Just as the piano can be broken or a string of a violin can go missing, it is indeed possible that physical variations in the brain cause intellectual capacities to vary. Snapping a few keys or over-tightening a few strings affects the sort of sounds the piano can produce. Thus, there is definitely a connection to the physical instrument and its expression. But the possible tunes that can be created on the broken piano are once more infinite; hence there can be no calculable difference between the working piano and the broken one, in terms of its music. In addition, the piano works due to the laws of mechanics: vibration, lever action, pushes and pulls, pressing of keys, etc. Everything can be calculated, as to how each key can be pressed and each sound produced. *It is the number of possible tunes that is not calculable*. Modern biology focuses entirely on electrical actions and cell behavior, just as if a person who wanted to learn music were to take the piano apart piece by piece to determine how the sound is created. This would naturally lead nowhere as far as music is concerned, since music lies in the combinations of sounds, not in their mechanisms. Similarly, creative thought lies in its capacity to generate fresh ideas, and not in amino acids, neurotransmitters, and network interconnections. This shows the key difference that takes place in calculating the capacity of human thought and that of machines.

It might be argued that the piano has a player who affects it from outside, and there is none who can be observed to act as the "player" for the brain. Here is where internal observation comes into play, the very same observation that enables one to observe one's own thought processes and define notions such as "consistency," "logical," and "internal effort." Ideas of logic and concepts do not occur by peering through a microscope, but directly from an individual's experience of them, which are later confirmed by looking through any instrument. Therefore, there is indeed a player, *the human individual*, whose thoughts leave an impression on the brain via electrical impulses in the same way a piano player leaves his impressions on the piano via the keys.

If numbers *have* to be used to get an idea of the difference between musical instruments and the human brain, consider this: Music consists of a few basic notes, and there are new tunes being produced even today. Calculating the number of songs ever sung would literally take forever and is infinite. If a few octaves of notes have been the basis of all the infinite music ever played and will be played on instruments, what indeed could be the capacity of 100 *billion* neurons? That gives the real qualitative comparison of human creative capacity, as a quantitative one is not possible.

The Digital Transition

> *Before Turing, things were done to numbers.*
> *After Turing, numbers began doing things.*
> – George Dyson, *Turing's Cathedral*

Mathematics and logic form the mold into which technological applications are cast. As brought out in the previous chapter, far-reaching modifications were made to logic, and this effect carried through into mathematics as well. The way in which this change in logic, and the corresponding change in mathematics, determined the range and capacity of further technological development will be the focus of this chapter.

As the 20th century dawned, mathematicians in Europe continued work on formal mathematics, attempting to define a fully consistent set of axioms based on the rules of symbolic logic. This transition from self-evident truths to axioms as a basis for mathematics was completed with the monumental work by Bertrand Russell and A.N. Whitehead: *Principia Mathematica* (1910). At the precise point that mathematics transitioned into the abstract realm, technology came to the fore in a very real and powerful way, via World War I.

The Great War, as it was called, was the first one in recorded history that depended heavily on technology. Trench warfare led nowhere, shifting the emphasis onto bigger and better guns. The use of mechanical calculators received a huge boost due to the need for accurate firing ranges of missiles and cannons. Even though digital machines such as Herman Hollerith's mechanical census tabulator had performed well enough to be recognized in the mainstream, analog machines (with continuous motion) dominated the calculations during the war. If there was any aspect of art or aesthetics involved in the design of earlier mechanisms, it was crushed out by the war and replaced by the aspect of utility. Deadly accuracy was the need of the time. Similarly, inner effort was almost entirely devoted to formulating strategies. It was in the midst of this upheaval that a small circle was pulled together that would have a major role in the rest of the century: Veblen's circle.

As described in George Dyson's book, *Turing's Cathedral*, this small workforce of mathematicians employed by Oswald Veblen for calculating gun trajectories consisted of people who went on to make significant contributions to the development of computers.

> Veblen organized the teams of human computers who were placed under his command, introducing mimeographed computing sheets that formalized the execution of step-by-step algorithms for processing the results of the firing range tests. It took the entire month of February to fire the first forty shots, yet by May his group was firing forty shots each day, and the growing force of human computers was keeping up. Veblen recruited widely, with a knack for discovering future mathematicians and making the best use of their talents during the war. (*Turing's Cathedral*, p.40, 2012)

In addition, Veblen later helped set up the Institute for Advanced Study at Princeton (1930), which became the mecca for many talented mathematicians and physicists: Albert Einstein, John von Neumann, Kurt Gödel, Alan Turing, Claude Shannon, and Robert Oppenheimer. It was mainly in this Institute (and nearby Princeton University where Alan Turing worked) that the achievements of computing theory and technology were concentrated. The IAS was to computers what the School of Athens was for logic. It is quite illuminating to study this development in some detail, with attention to the concepts introduced by some of these workers.

Even though the mathematics for digital circuits was available since the late 1880s with the works of Boole, Frege, Peirce and others, it was only in 1937 that they were actually applied. Claude Shannon, who was aware of the works of Boole, realized that the algebra lent itself for use in switching circuits for telephone networks. Thus, a practical application of symbolic logic was determined for the first time. The effect of this discovery has been so influential that Shannon's thesis has been called "possibly the most important, and also the most famous, master's thesis of the century." Until Shannon, computing was carried out only with analog machines, e.g., the Differential Analyzer which was used to integrate differential equations necessary for missile and bomb trajectory determination. Only after the application to switching and logical circuitry was it possible to build a practical digital computer, marking the birth of the digital era.

This transition from analog to digital has a parallel in mathematics as well. As pointed out previously, the transition from Logic in general to Boolean Logic involved the sacrifice of infinite quantities, which cannot be represented either mathematically in an equation or mechanically. Even though all mathematical operations could be encoded, the numbers themselves had physical restrictions. This meant that all signatures of the concept of infinity had to disappear from the number line. Consider the number line below:

What are the categories of numbers possible? If a, b, c represent the digits, they can be classified as:

–Integers (a, b, c, -a, -b, -c etc.)
–Rational numbers (of the form a/b)
–Irrational numbers (5√a, 3√b etc. with a and b prime)
–Transcendental numbers (π, *e*, πa, *e*b, etc.)

Of these, only the first two can be measured exactly, and also constructed by ruler and compass. Most of the irrationals and all of the transcendentals cannot be calculated. Even though all these numbers exist on a number line one draws with the sweep of a pencil, only the first two sets allow manipulations and calculations. For example, there is no way to indicate "7√7" (7th root of 7) or "π" exactly on a number line, even though one can easily draw a continuous line from 1 to 2 or 3 to 4. This is the key principle that defines whether or not a number can be utilized in a mechanical process.

Machines can therefore be used to conduct operations on integers and rational numbers only, while for the other two, approximations are naturally involved. One can add, subtract, multiply and divide only using the integers and rational numbers, and the mechanisms which generate these functions together constitute an *analog computer*. Even ruler and compass, or folding in origami, is something that shows an analog operation.

Since irrationals, trigonometric functions, and logarithms are not constructible in general, for centuries the only possible way to obtain them has been through tabulating them empirically and looking them up when required. This meant that mathematicians spent considerable time in creating these tables for later use. These are not accessible to any known machine and are beyond the domain of *exact* calculation. Hence, the limits of analog computers are reached with rational numbers.

What are the numbers that can be represented digitally? As the name suggests, only those using the digits (fingers), namely the countable numbers. Negative numbers and decimal fractions cannot be represented directly in terms of 1s and 0s, they can only be encoded so that the sign of the number or the placement of the decimal is added as an additional string of digits. Nor can recurring decimals be represented, e.g., 1/3 can only be approximated as 0.3333333. All irrational numbers are impossible to calculate in finite time; this ultimately restricts the set of numbers to whole numbers, i.e., 0, 1, 2, … n, where “n” is as large a number as is physically possible to represent. This forms the range of a digital system, as a direct consequence of Boolean algebra. A digital computer can be 100% accurate only with integer addition, subtraction, and multiplication. Any other operation involves approximations.

This means that the range is reduced when one transitions from the ideal analog computer to the ideal digital computer. This mirrors the development of Boolean logic, which jettisons most of the comparisons except equality, and thus reduces the range of the copulas previously in use. Logic and Mechanism hence move in step with each other. The fields of mathematics generate the corresponding mechanical operations thus:

Geometry =>
Construction with compass/ruler =>
Analog machines

Arithmetic =>
Integer number operations =>
Digital machines

It was important to go into this much detail regarding this transition because, in addition to the discovery of the use of Boolean algebra in circuitry, several mathematical and logical identifications were made at this time with regard to computation. These were intimately connected to this transition into the digital world, since the focus now shifted from *geometric analog construction* to *arithmetical digital computation*. While the Greeks focused on finding out if a certain statement was *true*, developers of symbolic logic focused on finding out if a certain statement was *provable*, and formal mathematicians focused on finding out if a statement is *computable*. Concomitant with this, all the struggles of the Greeks with paradoxes in logic were recast as problems of proofs or problems in computability.

The early problems with logic can be shown with a classic example: the Liar’s paradox. This paradox (attributed, among others, to Epimenides) is generally stated as:

Epimenides (a Cretan) says: All Cretans are liars.

Is this a true or a false statement? If it is true, it implies that it is false, and if it is false, it becomes true. A stricter example is a sentence like this: *This sentence is false.* (Hehner 2014) Thus, right at the core of logic, a self-referential statement generates an absurdity, bringing into question the very ideas of true and false. This has been tackled in numerous ways for a long time by logicians. However, in the 20th century, two mathematicians recast the resolution of this problem into modern form and shifted focus from "truth" to "provability" and "computability." They were Kurt Gödel and Alan Turing, whose work appeared at the same time as Shannon's.

Kurt Gödel directed his attention to one of the questions posed by David Hilbert regarding formal systems of mathematics (1928). Hilbert asked whether such a formal description can ever have a complete and consistent set of rules. Since formal mathematics added several axioms, it was of primary importance for this system to be fully consistent if it was to be valid. Gödel found out that this was not possible and one could always find a statement that could not be proved within the system, making the system incomplete. This is the precise analogue of the Liar's Paradox cropping up once again because the Paradox was not resolved but shunted from one domain to the other.

The meaning of Gödel's Incompleteness Theorem (1931), as this came to be called, is clearly described in this warehouse analogy by David Black:

> To understand the consternation experienced by mathematicians as a result of Gödel's discovery of the essential incompleteness of mathematical systems, imagine that a mathematical system is a large warehouse, and that each true statement in the system is a box stored in the warehouse. Naturally, boxes are counted when they enter or leave the warehouse, and records are kept of the number of boxes and their locations in the warehouse. Now imagine taking a physical inventory of the contents of the warehouse; the point of such an inventory is to record the existence and location of every box contained by the warehouse. The people taking the inventory must devise a path through the warehouse so that they can count every box, missing none and counting none twice. Physical inventories involve no magic; they must simply be carefully planned and meticulously executed. Imagine that the inventory is now complete, and the records on the warehouse's contents are now available for inspection.
>
> Gödel's proof demonstrates a method whereby any wise-guy warehouse man, upon looking over the results of the physical inventory, can enter the warehouse and turn up a box that does not appear on the records. Suppose the inventory records are corrected to include the newly discovered box; after looking over the corrected records, the wise-guy can produce another unrecorded box, and can keep doing so without limit. If you were the manager of the warehouse, how would this make you feel about your operation? Gödel's incompleteness proof engendered similar feelings in mathematicians about their knowledge of their own mathematical systems. (David B. Black, *Context and Significance of Gödel's Proof*, Shoreline Vol. 4, p.55, 1991)

This theorem can be applied to describe the behavior of points on the number line exactly. Just as between any two numbers one can always find another number that wasn't counted before, in the set of algorithms, one can find one which wasn't recognized before.

While Gödel concentrated on whether a system of formal mathematics was complete and consistent, Alan Turing tried to find out if it was possible to say beforehand whether or not a certain statement could be proved (1937). Since a proof was intricately tied to mathematical mechanism, as shown earlier, generating a proof depended on whether a number was computable or not. And what did he mean by "computable"?

"*According to my definition, a number is computable if its decimal can be written down by a machine.*" For example, a recurring decimal is called computable because the rule to calculate it can be encoded into the machine. Similarly π and *e* can be expanded in terms of series expansions, and are called computable by Turing.

$$\pi = 4\,(1 - 1/3 + 1/5 - 1/7 \ldots \infty)$$

It is at this juncture that the classic "bait-and-switch" can be identified: The computable number π is something that can be computed, as long as *infinite* time and memory are provided! This is really as meaningless as saying that it is possible to do something, with the minor problem that it would literally take forever to do. The very definition of computable numbers is fundamentally flawed, as they are by definition not computable. One can find a pattern to them, just as π generates a circular pattern, but that is a far cry from actually constructing a length π units long, which is not possible by calculation. Turing's concept of computable numbers does not address this issue (numbers that go to an infinite number of decimal places) but instead pushes it under the rug.

Secondly, the entire exercise of provability, paradoxes, computability, etc., can be illustrated by a simple example. Consider a group of people, say a dozen, and assume their talk is being studied by one interested researcher. There would be several statements which might be true, several lies, and several mixtures in their speech. If one among them declares aloud, "I am lying right now," he or she has uttered the Liar's Paradox. If the sentence is true, it is false (a lie), and if it is false, it is true, making it stuck in a loop. In a second scenario, assume that all the people are saying the exact same sentence. There is no way of saying if all of them are lying or if all of them are telling the truth.

These two situations exist, and the only way the truth of the matter can be adjudged is if there is a real event corresponding to what is being told by all of them and also experienced by the researcher. Since this depends on the experience of the researcher, logic necessarily has its limitations. This is the limit all logicians come up against.

However, Gödel converted the question of truth into one of provability and restated the Liar's Paradox in the language of formal logic with his Incompleteness Theorem. Turing's notion of computability was flawed, but nevertheless his attempt to reduce a system into computable and non-computable faced the same barrier, leading to his descriptions of the Halting Problem, which is "just the Liar's Paradox in fancy clothing." (Hehner, 2014) In addition, he also hit upon the same problem of verifying the truth of a statement, which cannot be done by staying within the logical system, be it by computing or by anything else. He therefore concluded that there was no way one could say beforehand by any method if a certain statement was computable or not.

Hence, this entire development had the effect of hiding the irrationals and transcendentals under the guise of computability, while the actual problems with logic were not resolved, but simply recast in a new language. The reason for the persistence of these logical problems was that the logic developed by the Greeks was still being used, only with more axioms and a smaller set of interrelationships (symbolic logic). The child inherited the defects of the parent, so to speak.

With the transition into digital machines, parallels with Greek development of logic are now mostly complete. They can be represented like this:

GREEK	MODERN
Aristotle	Boole
Stoics	Frege, Peirce
Epimenides	Gödel, Turing
Geometric construction	Digital computation
Euclidean geometry	Boolean algebra
Logic	Symbolic logic

It appears that this connection to Greek thought was missed by most people involved in the development of computers, who were really stimulated by Turing's work to build a machine that could compute anything. With the success of Shannon's circuits and Boolean logic, it was increasingly taken for granted that all thought processes can be expressed using Frege's symbolic logic, and that it can all be mechanized, even if it takes infinite time to arrive at the result (an illogical idea by all standards). Hence, the effects of irrationals and transcendentals were neglected and brushed to the side, while the essential problems that plagued Logic itself were not tackled directly, only reformulated.

Following the contributions of Shannon, Gödel, and Turing, the task of making digital machines feasible was taken up very effectively by John Von Neumann and his collaborators. This last leg of historical development, which continued up to the end of the century, will be described in the next chapter (to appear in *Research Bulletin* 22-2, Autumn/Winter 2017).

Editor's note: The references for this article, published in three segments, will appear at the end of the third installment (*Research Bulletin* 22-2 Autumn/Winter 2017).

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Technology and the Celebration of Work as Developed in Waldorf Education

David Mitchell

[Editor's comment: This article was first published in the *Waldorf Journal Project #19,* April 2012. David Mitchell, the late co-director of the Research Institute, was both prescient in anticipating the challenges that technology would increasingly present and articulate in describing the countermeasures that Waldorf education offers.]

We live today in an exciting, fast moving, and astonishing world! Rockets have lifted men and women across 230,400 miles of emptiness to explore the desolate, crater-pocked landscape of the moon. Machines have been designed that allow us an unprecedented ease of living. Time is like a snowflake in our hand: It disappears while we are deciding what to do with it. Our work week is shorter than ever before in history, and we find ourselves with large amounts of leisure time. This allows us more time to confront ourselves! It also presents us with interesting problems! How do we fill this time? What is the relationship between our thinking and our will life? Can we use our thinking creatively? Are we self-stimulating and able to continually educate ourselves? In this article I would like to explore the relationship between creative thinking and the ability to "do" work within the realms of technology and education.

Today's students need to be made aware of the importance of cultivating different thinking styles at a time when mankind's left brain activity is promised a rest. Neurocomputers, designed to imitate the structure and functioning of the human brain, are being developed to take over everything mundane and repetitive. Already we have computers that can speak, follow voice instructions, manipulate immense lists of facts, make music, and perform robotic tasks—all more error-free than humans.

At the same time we are exposed to telecommunications that connect us almost instantaneously with events as they unfold around the globe. Time and space have become compressed, human potential has been expanded, and the world meets us in our living room! We are both informed and comforted. My house has a heating system that is controlled by a miniature computer thermostat. I program it and, as the advertisement contends, I won't have to worry about being too hot or too cold ever again! We owe this all to technology.

We in the West are witnesses to the fact that, in a single generation, technology has changed our way of life. Yet, how many of us really understand this technology? More importantly, what is our responsibility as educators to bring technology in the correct way into our curriculum? How are we encouraging inventiveness and fostering a love for work in our students?

No one can deny that life has become easier on the physical plane as a result of technological innovation. Some regard technology as the universal benefactor, the distributor of science's bounty, successful in almost every undertaking to which it has turned its hand. However, a shadow side exists, which has become more and more apparent in recent years. The byproducts of technology have spread pollution on such a scale that scientists warn of an impending danger to all life on earth. It is a paradox that the more time we have for ourselves, the more mechanized our civilization, the more hectic and stress-filled our lives have become, as well. We find that we need the extra hours we save each work week merely to rejuvenate ourselves physically and mentally. How does education help us to deal with this?

A task of education must be to aim technology in the direction of the long-term well-being of humanity. To do this one must develop a curriculum to discuss the above questions, recognize one's motivations, and be able to exercise moral judgment.

During recent years there has been much soul searching with regard to the aims and direction of modern education. The ancient Greek civilization knew its educational aims. The foundation for all learning was wonder—otherwise there could be no impulse to explore. In the early years of a child's education, poetry, music, and movement were developed so that in more mature years there would be an understanding for mathematics and philosophy. To guide the social life, the religious leaders gave moral instruction through the great dramas written by Euripides, Aeschylus, and Sophocles.

In the 17th century when the modern scientific outlook was born, education took a new direction. Descartes gave the Western world *defined thinking*. He said that "consciousness is attributed exclusively to the brain and nervous system."

In the 20th century, educator and philosopher Rudolf Steiner said that if a person reflects upon the powers of his mind or soul, he will soon discover that he has the capacity of expressing himself in three different soul worlds—thinking, feeling, and willing. We can experience many different kinds of thinking, from pure logical thought to the rich, imaginative pictures of new ideas. The realm of feeling can be experienced as cultural appreciation or as spiritual experience of ecstasy or devotion. The will life exists from instinctive impulses to conscious, deliberate acts. An educational task is to lead the will from the control of the feeling into the control of the thinking.

All education starts with the teacher's inspiring interest in the feeling life of the students. It then goes on to the activity of the limbs, and, lastly, the thinking is stirred. Thinking is objective, conscious, analytical. Feelings are subjective, personal, colorful, and less conscious. The life of the will is very subjective, individual, and the most unconscious. Wisdom is acquired by a process of reflection made possible by a short pause in will activity. Waldorf education strives to educate and harmonize these three realms, but it is in the realms of thinking and willing that we find the seeds of technology. It is man's thinking and inventiveness that has brought about technological innovation. Curiosity, playfulness, and imagination are qualities that should be encouraged in education if we wish to perpetuate technological growth.

> The process of technological innovation depends on intellectual spirit—on the willingness to face change, to take risks. It requires creativity, analytical skill, and an independence of mind.
>
> – Frank Newman

Schools Need to Help Cultivate a Love for Work

At the beginning of this century, most students came from a rural, working environment. Their father was a farmer or a laborer. The purpose of going to school was to learn to think. At home they were occupied by activities which exercised their will and made them feel useful. They learned to "do" things out of necessity.

Today, most students come from an urban setting and their parents leave home to go to 'work.' The activity of the parents' work is invisible to the child, and the direct results are not always experienced or appreciated by the family. Life and work have become abstractly separated.

At the same time the media is omnipresent and fills us chockablock full with information. Today, a type of pseudo-thinking is learned outside of school. We are fed lots of information, but information is not education. Information does not properly exercise the will, nor is it satisfying for the soul!

The heads of many youth are filled with trivia; they have lost contact with real work. This task of learning about “work” has been passed over to the school. Today’s students need to be taught to use their capacities, to apply their thinking in such a manner that they are able to do something with it. They are desperately in need of developing practical skills and building up their self-confidence and independence.

Waldorf Education

Thought activity is cultivated through an approach to the subject by which the phenomena are studied and evaluated before conclusions and theories are drawn. This process leaves the student free to develop and exercise the capacity for judgment and discrimination. Work in algebra, Euclidean geometry, and bookbinding strengthens the logical thinking, while projective geometry and experiencing the history of mankind stimulate imaginative pictorial thinking.

How the teacher phrases the questions that put the student’s mind into activity is all important. He or she must train the student to look at situations from various points of view and become able to use synthetic and analytic approaches to problems.

Thinking is not, however, the only part of an individual to consider in education. Adolescents often arrive at their high school asking the following questions: What really matters? What is the point of it all? Who am I? To deal with these questions, the teacher must penetrate beneath the surface of the subject. The students must be stirred—their enthusiasm must be kindled. They must care for what they are doing and desire to do their best at it. Waldorf education strives to educate the feeling life as well as the thinking. The tools they use are drama, painting, cultural activities, music, sculpture, art, and the time the teacher gives to the students to express themselves.

Once the student has been connected to the subject through his feeling for it and awakened in his thought life, then the knowledge can flow into his will, into his active deeds. A Chinese proverb states the following:

> When I hear, I forget.
> When I see, I remember.
> When I do, I understand.

In Waldorf education the education of the will is an equally important part of the threefold approach to education. In the academic area, the students are asked to write their own main lesson books and create their own projects. In the practical realm, we offer courses in house building, stone carving, pottery, blacksmithing, and other crafts.

Idealism is kept alive by the curriculum where all the subjects are centered around the human being. In the main lessons on art history, literature, poetry, music, and architecture, the evolution of mankind is traced from ancient times through the Medieval and the Renaissance up to the Modem Age. A life philosophy is evolved in which science, art, and religion are not artificially separated; the qualitative as well as the quantitative is cultivated. When the students study the computer, they should also be able to learn something about themselves!

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Steiner identified two great obstacles that face adolescents, and he offered suggestions as to how a curriculum could be formulated to assist the youth in meeting them. The first is “sexual lust,” which can be met in them by keeping them busy with meaningful tasks, by encouraging them to strive for beauty, and by keeping their hands busy with such Waldorf school subjects as handwork, jewelry making, blacksmithing, stone sculpture, woodcarving, and joinery.

The second danger is the "lust for power." To keep them from falling victim to this, the teachers must inspire the teenagers' thinking. They must bring great ideas to them and moral thoughts. They must keep the intellect moving and help them develop altruism. They have the task of helping the students come out of their self-centeredness and of guiding them to help others through service-motivated activities, such as cleaning trash from a road, clearing a forest path, helping at a home for the elderly, or working on a farm.

To be absorbed in creative activity is the real fun of life. This process creates rather than depletes energy. One can feel relaxed, in control, at peace, and in harmony.

The puberty experience is one of death—the child dies, the adolescent is born. One of the most powerful agents in overcoming these death forces is to allow the children to model and carve, to transform material enlivened by the forming power of their own human spirit. In carving and modeling the children can find an excellent outlet for their creative energies. It is difficult, if not impossible, to be absorbed in pursuing a meaningful goal and to be depressed at the same time.

[A]rts and crafts work as a preliminary stage of technical education and are considered indispensable if the pupils are to engage with social competence in the work processes of a technical culture.

The crafts program of the Waldorf school is an example of how this takes place. Both arts and crafts work as a preliminary stage of technical education and are considered indispensable if the pupils are to engage with social competence in the work processes of a technical culture.

The Case for Crafts

Mythology is full of stories connecting weaving and knot-tying with wisdom. A few examples are the puzzle of the Gordian knot, which Alexander the Great solved, and the thread trailed out by Theseus in the Labyrinth on Crete, with its mysterious thousand paths. The string and cleverness allowed Theseus to defeat the Minotaur. Athena, called the Inspirer of all Arts and Crafts, was born out of the head of Zeus and ruled over the world of thoughts. It is the crafts that teach the students to meet and overcome problems. They become engaged in an activity that on the one hand focuses them, and on the other hand can lead them through the eye of the needle whereby they become transformed by the process.

Practical activity builds confidence in the students. The students need to experience that work is wonderful, that work can be a joy. Confidence is the key to academic success. By engaging in practical tasks the students "learn how to learn." The more interests and skills we can develop in our students, the more fully they will participate in life.

There are stages for each activity. First the student must think or imagine the task, then he must prepare, research, and experiment. This is followed by a very important incubation period during which the idea is allowed to rest so that new directions may emerge. Finally the task is begun, completed, and reflected upon. Lastly, any modifications that need to be made are done. These stages exercise both the thinking and the will life.

Examples from the Waldorf Curriculum

Education of the human being is meant to be a lifelong learning process, especially in the vocational field, rather than a cumulative addition of pre-determined knowledge and skills. When we take the ability to learn and combine it with self-confidence and optimism, we have the capacity for lifelong learning. How admired are those individuals who are able to learn something new up to the day of their death!

In the classroom we recognize three groups of students. There are those who make things happen. Then there are those who watch things happen, and finally there are those who wonder what happened! Those students who are strengthened in their will activity are usually the ones who make things happen. They are confident in themselves and not overly concerned about making a mistake. We must teach our students how to adapt the mistakes they make, rather than start over again. The students must not be overly concerned with making mistakes because fear of mistakes will cripple their progress. The only way to avoid mistakes is to avoid action. This is not something we want to encourage. What we want is courage and confidence, and this has been observed in students who have mastered practical activities.

The teacher's proper attention to detail in practical skills during the elementary school years can metamorphose into intellectual dexterity in the teenage years. In the early years in a Waldorf school, work is developed as an outgrowth of play. In these primary years the teacher sets the foundation for the high school. The student should leave the middle school with a craving to know, an insatiable curiosity about everything that goes on around him, such that he can convert this curiosity and craving for knowledge into still further knowledge.

In grades 7 and 8, the students work with wood, metal, stone, and fabric. The woodworking includes carving convex and concave objects such as bowls and spoons, each of which has been designed with functionality in mind. They also meet stone carving, in a material such as soapstone which they craft into animals of their own design. Careful observation is developed as the children chisel, rasp, and sand toward completion. In craft work the key to development is learning to be patient. Students are asked to remember that the chick arrives by hatching the egg, not by breaking it open with a hammer.

Woodworking is taught from grades 4–12 and demands the perception of the unique characteristics of each piece of wood as the different quality, texture, color, and density are examined. Measuring, cutting dovetails, and fitting joints merges with carving, rasping, and sawing wood. In carving a piece of twisted elm, one learns to find form hidden within the grain and thus allow it to emerge out of the wood. Each wood requires a different blade or gouge stroke. Each wood reveals to the carver its fast or slow growth, its moisture or dryness, calling for varying degrees of accuracy and finish techniques.

Copper work in grades 7–9 initiates the pupils into working with metal. In woodworking the students have a close connection with the source of the material they are fashioning—the tree. However, copper is a product of a technical process that is most likely unknown to them. Transforming a flat piece of sheet copper into a vessel, by series after series of carefully-aimed hammer blows while shifting it spirally across the form, must be a slow, flowing process or else the material will become too thin. The soft, red glow of the copper may warm them but they can immediately feel its hardness and rigidity. The noise of the hammer striking it in a hardwood mold is sharp and assaults the ears; the odor of the hot, annealing metal irritates the nose. The senses are fully engaged.

Their first task is to smooth the edges with a file; then it is textured with light hammer strokes spiraling out from the center on a hard steel form. Only through rhythmical beating does it soften and conform to the craftsman's intended shape. Then after continuous pounding it becomes hard and brittle and needs to be softened again by fining, followed by quenching in water, whereby it abruptly changes color. Then the hammering continues until a small bowl is created.

Finally it is buffed and polished to a high luster. The technique is repeated in more complicated ways in the upper grades for jars and vases and ladles. The students learn that rhythm saves strength. Ten days of hammering is needed to make a vase. For twenty hours each stroke must be identical to the one before it in order to produce a beautiful form. Stamina is developed. Working with copper develops a feeling for form and space as well as rhythmical mobility.

In the pottery shop the students dig their hands into a tub of moist, brown clay. It is cool, heavy, and malleable. Slowly they exert pressure from the outside and it is turned into a sphere. They press their thumbs into one side and press a hole in it and turn it so that the walls are proportional. A vessel has appeared—and this was a lot easier than with copper! The selection of glazes and firing techniques is an exploration of chemistry. There is a lot of room for trial and error, for experimentation.

Blacksmithing in grades 8–12 develops character as well as manual skill. Respect for the power of red-hot metal comes quickly to the aspiring blacksmith, and there is no time for timidity because the metal has to be worked with spontaneity and focus. Life today is also fast-paced and demands immediacy. The worker must use his strength energetically, even explosively! There is no room for hesitation, because once the metal cools, it loses its plasticity. The time is very short. The look on a student's face when she transforms a ¾"-square stock into a multiple twist pattern with relative ease is a sight to behold. Confidence is developed. The forge trains powers of decision. The blacksmith learns the fundamentals of the craft: keeping the forge fire burning, not allowing an oxidizing flame, handling the tools in a proper fashion, and developing an understanding for the laws of metallurgy.

In a Waldorf high school you may also find other practical courses such as house building, carving, spinning, dying, bookbinding, sewing with both treadle and electric machines, lock-smithing, papermaking, shoemaking, surveying, soap making, automobile mechanics, batik, calligraphy, stained glass making, stone carving, furniture making, pottery, and jewelry making. All students participate in various phases of these courses, and as they progress through the school, some may focus on one craft to develop an expertise in it.

In the high school everything that man himself has created through nature and the recognition of its laws should be penetrated with comprehension. Technology has issued from such comprehension. Steiner said that each man who uses a streetcar should know technically what happens so that he really understands how motion is accomplished. He said, "We are living in the midst of a world produced by man, formed by human thoughts, which we use, and which we don't understand. This fact—that we understand nothing of something which is formed by man, of something which is basically the result of human thoughts—has great significance for the entire sphere in which the human soul and spirit lives."

…[E]verything that man himself has created through nature and the recognition of its laws should be penetrated with comprehension. Technology issues from such comprehension.

Academics and Technology

Academic classes in Waldorf schools also pay attention to technology from grades 8–12. For example, in the 9th grade history class, the students study the Industrial Revolution. Through vivid pictures they learn from their teacher of life in the mines, of child labor in dark, crowded English factories, of oppression and suffering. They learn of agricultural invention and the promise of a better life. The study of the Industrial Revolution brings young people to confront the issues of their times. Concerns for the underprivileged, the question of power and authority, and the overwhelming domination of economic values over society are issues that today's Waldorf high schools have to address.

The physics classes in the Waldorf schools are dedicated to giving the students an understanding of the telephone and the steam engines in grade 9; weaving, spinning, turbines, the internal combustion engine, the electric motor, and technical mechanics in grade 10; electricity, magnetism, and atomic energy in grade 11; optics, photometry, and chemical technology in grade 12.

Computer Science

When we think of the word "technology," the word "computer" is often the next word that comes to mind. The following course description is for readers of this article who consider themselves avid technophiles. It illustrates how an 11th or 12th grader might find a computer course in a Waldorf school.

One course that I was instrumental in designing back in the 1980s, when computers were beginning to enter the home life with the advent of the PC, had three fundamental components. The first was to identify the myths and realities about computers. What is it that they do and what do they not do? The next steps were to discuss linear thinking and flow charting —the students could learn how to think like a von Neumann computer! Then flow charting moved into programming and the concept of a procedural language. Artificial Intelligence would be discussed, and the students would write and apply a simple program. The sociological implications of computers would also be debated.

In the second section on computers, the students would investigate programming and the nature of computer languages. Students would write and debug a number of small basic programs. They would work through flow charts for making chocolate-chip cookies and for starting a car. They would also be called upon to imagine themselves as bankers and write a program to develop interest rates and percentages on borrowed money. This section involved the history of the computer including the biographies and work of Pascal, Babbage, and Lovelace. Programming concepts would be addressed and a program for a simple well-known game like Tic-Tac-Toe would be written and debugged by the students. Machine and assembly language would then be introduced as would fourth-generation languages. The students would then be given many exercises to practice programming and finally to learn how to recognize and overcome computer addiction.

The third component of the introductory course involved looking at the inner structure of a microcomputer and the way in which machine languages work. Students would review Boolean algebra, de Morgan's Law, and the binary number system. Using wiring boards (called breadboards), chips, switches, and wire, they would build a one-bit adder, an R-S flipflop using only NAND gates, and four bit J-K shift registers. They would take on the study of logical propositions and logical manipulation as a new kind of mathematics. Then they would take breadboards and build simple and complex circuits. This would give the students a practical experience in building their own computer.

These three sections would be interspersed with trips to a silicon-chip factory, a company using industrial robots, a corporation such as a national motel chain that sets all its reservations by computer, or a large store that controls its inventory and sales through the computer.

Thinking Fructified by Practical Activity

Recent neurological research has confirmed that mobility and dexterity in the fine-motor muscles, especially in the hand, stimulate cellular development in the brain, and so strengthen the physical instrument of thinking. Many forms of thinking (analytical, synthetic, teleological, causal, etc.) need to be learned in today's complex society. It is our task as teachers to apply these various thinking techniques relative to the subject matter we are teaching.

> The principal good of education is to create men who are capable of doing new things, not simply of repeating what other generations have done. – Jean Piaget

In cognitive development Waldorf schools aim to develop the training of judgment and discretion. The capacity for conceptual thought lies on a higher level of cognitive development. The process of abstraction can be exercised by having students analyze their own work. The method of examining why a piece of copper became too thin in a particular area or why a joint of a compound dovetail didn't fit lends itself to such mental evaluation. Self-observation, self-evaluation, and the capacity to take on responsibility are characteristics of personal growth.

The task of the teacher today is not to structure the minds of the students, but rather to enable them to grow to new dimensions that may even exceed our own understanding.

Skill learned in the crafts becomes the development of practical consciousness. This practical consciousness has its genesis in an increased power of observation. The training of the power of perception is extended in the upper grades to precise observation.

Handwork causes chemical crystallization in the body. Physical activity breaks it up and brings about a sort of rebirth or surge of energy. Hence, there ought to be a conscious rhythm of intellectual and practical activities throughout the school day so that the students can maximize their learning potential.

Extracurricular Trips and Projects

Waldorf schools find it positive to incorporate trips into the curriculum. A week is set aside at many Waldorf schools during which time each high school class has exposure to a different activity. The 9th grade spends a week working on a farm. They learn about the economy of the farm, working with animals, and the sale of byproducts, and they participate in all the practical work. They develop an appreciation for the rhythms necessary for working such long days.

The 10th grade spends a week working on forestry projects, clearing a mountain trail, building lean-to's, or surveying large land areas. They learn to identify trees and appreciate the diversity of wetlands.

The 11th grade may go to a factory and join the work of an assembly line for a week. In the evening there will be talks by the company president about the goals, by the treasurer about the bookkeeping practices, by a labor union leader about the working conditions, and by shop stewards about production levels.

The 12th grade will take on a task of social significance such as insulating the homes of inner-city slum residents, or a project on behalf of the local city with regard to homeless shelters, old-age homes, retirement homes, etc.

In addition to these projects, class-related trips based on technology are planned for every class so that they can connect what is happening in the classroom with activities that are happening in their immediate community.

Conclusion

The task of the teacher today is not to structure the minds of the students, but rather to enable them to grow to new dimensions that may even exceed our own understanding. In such a manner can the teacher of the present serve the future. Teaching must become a continual learning process for the teacher as well as for the student.

Educators can learn a lesson from industry. The 3M Company went from producing sandpaper to roofing shingles, to Scotch tape, to magnetic tape, to photocopying, and then to reflective signs. All of these products require a common skill: how to apply a closely-controlled layer of material to a flexible base. The creative thinking that evolved new products at 3M can be stimulated by a proper relationship between thinking and will activities in high school.

> Living is learning. When we are most alive, using most fully our energies, senses and capacities, we are learning the most.
>
> – John Holt

Self-esteem is central to the whole problem of security in our modern world. Self-esteem is also necessary to secure any type of success in any endeavor. No one is capable of reaching beyond the limits of self-imposed boundaries.

Practical subjects, artistic lessons, and activities involving the hand can no longer be seen merely as supportive and enlivening factors of the curriculum. Rather they are absolutely necessary in the education of a youth facing a complex and changing world.

By the time a student graduates from high school, he or she should have made a connection with the main technologies of our age—from the computer to an internal combustion engine and what happens when we flip a switch and the lights go on. It is necessary to understand these things in order to feel at home in the world. Otherwise we are not able to live in full consciousness. The ability to do, to be productive and well-rounded, produces the very independence we want in our students.

No individual will be able to retain his independence in our contemporary working world unless an emancipatory education has endowed him with the practical capacity to do so. An education is emancipatory only when it enables young people to expand and stabilize their individual personalities before they confront the conditions prevailing in a civilization dominated by technology. Education must train students to participate responsibly and creatively. We must see the technical and social changes of our time as a stage in the development of humanity.

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David Mitchell*, a Waldorf teacher for over forty years, took a class through eight grades before serving as a high school teacher in the life sciences and several practical arts including blacksmithing, stonecarving, and woodwork. For many years he was a leading figure in the Association of Waldorf Schools of North America (AWSNA), including serving as its founding Chair of Publications, in which capacity (1987–2012) he edited and authored a long string of articles, journals, and book titles. As Co-Director of the Research Institute for Waldorf Education, he gave the* Research Bulletin *its current form.*

Dyslexia in the Waldorf Classroom
Survey of North American Waldorf Schools

Lalla Carini

This survey is part of a larger study aimed at better understanding how Waldorf schools approach reading difficulties and what can be done better or differently to serve seriously dyslexic children.

As a class teacher and remedial teacher for the last eighteen years, I came to the conclusion four or five years ago that an anthroposophical approach to dyslexia and other reading difficulties has not been sufficiently articulated. In spite of insightful discussions of the complex phenomena of dyslexia by esteemed doctors such as Thomas Weihs (1971), Michaela Glöckler (2013), Walter Holtzapfel (2006), Armin Husemann (2002, p.290), and Karl König (2002), and the lifelong dedication of Extra Lesson founder Audrey McAllen (2004, 2002, 1998), no typology of reading difficulties, validated by current findings in the neurology of reading, is available to English-speaking Waldorf professionals.[1] In the latest revised edition of their landmark book, *A Guide to Child Health*, Drs. Glöckler and Göbel give a brief description of dyslexia. The section ends with the statement: "For severe cases, we recommend contacting a program that specializes in dyslexia therapy." (2013, p.388)

When should a family turn to specialized professionals? When should parents rather follow the strategies for support commonly used by Waldorf class teachers and remedial teachers? Can parents trust that the screenings used in Waldorf schools are accurate in identifying a serious reading difficulty? Can teachers feel that they have been well prepared to identify and address different types of learners with respect to literacy development, and to what extent? It has been my experience, as a Waldorf class teacher and remedial teacher who has also trained in a variety of mainstream approaches to educational therapy, that Rudolf Steiner's overall methodology for teaching reading and writing has elements of genius when applied to the slower or different learner. However, remedial teachers trained in the Extra Lesson often lack the training or experience of the class teacher. The training that remedial teachers receive is quite broad in scope, and does not specialize in literacy issues. In recommending intervention to anxious parents, Waldorf professionals often find themselves in conflict between two extreme positions. One position relies too heavily on the child's ability to "outgrow" a learning difficulty, the other rushes to seek a "fix" through approaches that were created to fit the timeline and context of the mainstream classroom.

In practical terms, when a child is not reading fluently in the second, third, or fourth grade in a Waldorf school, does this mean s/he needs specialized help? Will this child develop gradually the analytical skills required for proficient reading? Or will s/he stall and suffer in self-esteem if not met with a specific intervention? Questions coming toward Waldorf parents and teachers from specialists working with the mainstream also include: When do you expect the typical child to learn to read in a Waldorf classroom? How do you understand early detection? Do you practice early intervention, and, if so, in what ways? The survey I conducted serves to clarify which of these questions live most strongly in the schools and which are already being addressed. Short of giving full answers, this report will point out some of the perceptions and opinions that may need to shift before teachers can work in full confidence with parents and professionals to meet the needs of these children.

A Word on the Label "Dyslexia"

What is *dyslexia* and why would we label a child dyslexic? Dyslexia or *specific reading disability* is used in the mainstream to ensure that children who struggle to learn to read will not be labeled unteachable, as they were in the past, but rather will be met with the most effective known practices suited to their learning differences. Reading is a fetish in our culture. It is also a fundamental skill. The definition of dyslexia, as a difficulty with reading acquisition that is unrelated to the child's overall cognitive abilities, points to a *continuum.* (Shaywitz 2003, pp.27–29; Siegel 2006, p.1) The continuum spans from children who, in our view, may have been forced to learn to read when they were not mature enough in their sensory-perceptual development, all the way to children with a specific neurobiological profile, most often with a genetic component. (Siegel) This profile is characterized by a number of significant gifts, which Drs. Brock and Fernette Eide designate collectively as "the dyslexic advantage." (Eide 2012).

Dyslexia or specific reading disability is used in the mainstream to ensure that children who struggle to learn to read will not be labeled unteachable ... but rather will be met with the most effective known practices suited to their learning differences.

There are pros and cons to calling children "dyslexic." In the first school years, children need to be seen and supported in the development of foundational capacities. As they get older, however, explicit dialogue about the strengths and weaknesses of their dyslexic learning profile has proven, in my experience, to be an essential strategy for supporting the child's self-esteem.

Historically, Waldorf teachers have resisted labeling children who struggle to read because they find that the Waldorf method, by supporting the maturation of all underlying capacities, could succeed in getting children to read fluently by the end of the grade school years. However, as early as 1988, in the report on the conference in Herdecke, "On the Present Situation of Dyslexia in the Waldorf Schools," Dr. Glöckler urged that teachers learn to distinguish "harmless, 'normal' spelling mistakes from the not so harmless, dyslexic ones." (1988) Reporting on the contribution of psychologist Peter Zimmermann, Dr. Glöckler stated the need to recognize this profile early and to address it appropriately at each stage of the child's development. In *A Guide to Child Health,* Glöckler goes as far as to say, "The appearance of physical and psychological symptoms [that stem from anxieties connected to reading failure] is a clear sign that the condition needs to be treated as an illness." She concludes, "Thorough diagnosis followed by individual help and support is required." (2013, p.387)

One aim of my survey was to determine whether Waldorf professionals distinguish dyslexia, as a specific neurological profile, from other learning issues. Such issues include the reading difficulties encountered by many children who simply need more time to develop the analytical skills necessary to master reading.

The Survey

I received 66 complete responses, providing data relative to 57 schools in North America. Of these schools, all but three serve students up to grade eight or beyond. Survey respondents include the following: 33 class teachers, some of whom also cover educational support duties in the school or are Care Group members, 20 educational support teachers with a variety of duties, 6 respondents not directly involved with learning support, and 6 working exclusively in private practice. Only one response came from a eurythmy teacher who is also a support teacher; no responses came from eurythmy therapists.

The survey was comprised of two sections. Section A focused on the monitoring and detection of reading difficulties. Section B polled perceptions and opinions about the current approach to reading difficulties in Waldorf schools. Following the survey, I interviewed six seasoned class teachers for their experiences with dyslexic students. Their responses further confirmed the general findings summarized in this article. They also strengthened the case for the questions that remain to be addressed.

The collected data show that Waldorf schools are succeeding in creating structures for educational support (80%) to help with prevention, screening, and intervention. Tutorial support is part of these efforts in most of the schools (70%). Eurythmy therapy is also offered (59%), but at a lower rate than both tutoring and educational support. Only 26% of respondents indicated that their school consults with an anthroposophical physician, and then usually on an irregular basis.

Teachers repeatedly raised the concern that the ability to monitor and address struggling students varies greatly from one class teacher to the other.

Monitoring and Detection

Given the continuum on which reading difficulties manifest, I consider it important in my own work as an educational support teacher to be clear at what point, on average, the gap between readers and non-readers in a class begins to widen. Most schools do not have quantitative data of this sort, even though they can easily be collected through yearly observational assessments.

For the survey I chose to pose the question of reading proficiency at two different points in time. The overall response I received is comparable to what I found in my school: Upward of 75% of children are deemed to be independent readers by the end of third grade; almost 90% read regularly for pleasure in sixth grade. The more specialized colleagues with a mainstream background, who think in terms of graduated readers and fluency rates, would have wanted more detail. However, I considered it sufficient to confirm that Waldorf schools teach reading successfully and that identifying a Waldorf timeline of reading development is important and helpful. In fact, in lectures given in Dornach in 1923, when Rudolf Steiner discussed the three methods for teaching reading, he stated that "if young pupils have been taught in this way, they will be able to read in due time—perhaps a few months after the ninth year. Depending on the child, this stage may occur a little earlier or later." (1996, p.83)[2]

Steiner also said that children who don't learn to read before the twelfth year may in the end be healthier, even "smarter," than those who read very early. The question for the teacher is: Do we know what we are seeing? My stance, shared by Susan Goldstein, an experienced teacher and mentor from Santa Cruz, CA, is that "if a child is not reading by the end of third grade, a Waldorf class teacher should know why that is so, and an open conversation should be happening with the parents about the child's learning profile."[3] This level of expertise in the teaching of reading is necessary for all teachers and certainly for anxious parents who want to trust the school with their different learners.

The survey confirmed that class teachers have complete freedom and independence in how they assess learning. Teachers assess learning mostly through informal measures. However, use of some formal assessments is becoming more common. Teachers repeatedly raised the concern that the ability to monitor and address struggling students varies greatly from one class teacher to the other, which is why educational support positions have been established. Many of the larger schools also offer small-group tutorial support. Most often, a resource teacher with mainstream training does this tutorial work. In my experience, simple phonics, reading, and spelling inventories used in the mainstream can add a helpful tool to a teacher's observational notes about their students.[4]

Brock and Fernette Eide (2012), authors of *The Dyslexic Advantage*, highlight the gifts that accompany the neurological profile associated with serious reading struggles. These include strong visual-spatial capacities, strong oral narrative abilities, strong interpersonal skills, and strong associative thinking. A simple test offered for free on their website[5] provides a general indication. When it comes to proper recognition of this specific profile, the survey showed a lack of such knowledge among teachers in Waldorf schools. In fact, 53% of respondents had no acquaintance with specific screenings that would identify such a profile, but showed interest in learning more about them. One such assessment is the WRAT-4, which might be helpful for schools that are feeling pressure to send children for outside assessment. Easy to administer, it is available for purchase by teachers with a master's degree.[6]

When a school administers simple screenings, it spares the parents from having to get a full assessment outside, which is not necessary in most cases until high school. Proper identification and treatment of seriously dyslexic students has been an issue in many Waldorf schools. Forty-six percent of respondents stated that they knew of children in their schools who "fell through the cracks." Some respondents spoke from personal experience, voicing disappointment that so little had been done to help their child. It is important to note that in one third of the schools polled, such incidents happened prior to the establishment of an educational support position, which was often instituted as a response to parent dissatisfaction.

Early detection is seen by dyslexia advocacy groups as a means to ensure that the gifts that accompany dyslexia are taken into consideration when choosing appropriate teaching strategies. Although many of these strategies are already best practices in most Waldorf schools, the six experienced colleagues I interviewed agreed that ongoing monitoring by resource teachers provides immense support to the class teacher. All six of these colleagues were able to maintain one or more deeply dyslexic students in their classes thanks to specialized programs set up by the parents within or parallel to the Waldorf program. In the upper grades accommodations were set in place to enable these students to succeed.

Early detection is seen by dyslexia advocacy groups as a means to ensure that the gifts that accompany dyslexia are taken into consideration when choosing appropriate teaching strategies.

Measures such as audio books and previews of reading assignments can contribute greatly to the success of a seriously dyslexic or struggling reader. The survey showed that the use of accommodations for struggling learners in the upper grades is limited to 44% of respondents. All teachers need to make conscious use of these differentiated strategies, which range from giving extra time for the completion of assignments to frequent conferencing for either more explicit instruction or oral assessment. Implementation should not be dependent on the goodwill of individual teachers, as is the case with 47% of our respondents, but should rather become best practice for all.

Perceptions and Opinions

The survey showed a solid commitment among the respondents to the Waldorf approach to literacy. Careful support for the maturation of the four bodily senses comes first, then an artistic approach with strong oral language experiences and the "writing road" to reading, then a patient recapitulation of missed steps once the time is ripe, and, I would include, much eurythmy and form drawing. Almost one third of respondents saw struggling readers thriving in the upper grades when given individual plans of support.

However, half of the respondents confirmed that a Waldorf approach to reading difficulties hasn't been sufficiently articulated. This calls for a more extensive sharing of success stories.

A statement by Abigail Marshall, a dyslexia specialist, on the inadequacy of the Waldorf classroom in meeting dyslexic students came right up when I searched online the words *Waldorf* and *dyslexia*. Responses commenting on her book, *When Your Child Has Dyslexia* (2009), confirmed my experience that a standard Waldorf school, with relatively large classes and no abundance of resources to pour into support systems, meets challenges similar to those in mainstream private schools, where parents carry most of the financial burden of remediation. The question is, again: What can schools do to minimize the need for families to pour extra resources into individual support outside school? Giving a clear presentation of the many options available in the greater community is helpful to parents, as well as a strong retention tool.

Careful support for the maturation of the four bodily senses comes first, then an artistic approach with strong oral language experiences and the "writing road" to reading, then a patient recapitulation of missed steps once the time is ripe.

Given all the forms of support that have been implemented in the schools during the last few years, it is not surprising that more than half of the respondents perceive teachers to be reasonably to extremely satisfied with the overall way they have been addressing reading difficulties. What shall we make of the other 45% who either feel teachers are not satisfied (30%) or do not have a way of telling? We should again hope that more schools invest in supporting their class teachers and that the benefits of this support will be shared with their communities.

The experienced class teachers I interviewed echoed Dr. Glöckler's advice: "In all cases … close cooperation among therapists, teachers, and parents is necessary." (2013, p. 388) This report highlights several questions that live in Waldorf schools around reading and literacy difficulties, both at the level of understanding the phenomena and teacher preparation, and at the level of school structures for support and communication with parents. The results of the Dyslexia Survey should serve to spur discussion, stimulate further research, and renew enthusiasm for solving the riddles that these different learners bring to our schools.

ENDNOTES

1. The most recent typology, developed jointly by anthroposophic doctors and educational researchers, was given by Dr. Michaela Glöckler 28 years ago, in 1988, after a conference held in Herdecke, Germany. A report on this conference, which I will reference here from a typewritten copy in English, titled "Are There Dyslexic Children in Waldorf Schools?", was published in the German periodical *Erziehungskunst* in the same year.
2. This timeline was given in the context of the German language, which has a far simpler spelling structure.
3. Private interview, March 2015.
4. See the rich word study resource *Words Their Way* (Bear 2008) for an example of spelling inventories.
5. www.dyslexic advantage.org
6. Wide Range Achievement Test (WRAT-4), G. Wilkinson, published by Pearson.

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Book Review

Postformal Education: A Philosophy for Complex Futures

David K. Scott

Postformal Education, as a title, may appear forbidding. However, the reader will discover a book on transforming education, in which the word "love" appears 189 times and "wisdom" 279 times. By contrast, the word "test," so prevalent in educational circles these days, occurs only 39 times! The contrast is reminiscent of a statistic from Darwin's *The Descent of Man*, in which the phrase "survival of the fittest" appears only twice while the word "love" occurs 95 times, as noted by David Loye. We seldom mention the word "love" in the teaching of evolution or education more generally. The reason may lie in the author's assertion: "What masquerades for education today must be seen for what it is: an anachronistic relic of the industrial past." Her solution is an education based on four core values–love, life, wisdom, and voice. Without "voice" in an age of proliferating communication devices and social media, the first three will be harder to incorporate.

However, the transformation is far from simple. As the author writes, "This book is not for the faint-hearted, or those wanting to tinker with the edges of the outmoded schooling model. It raises a planet-wide call to question how we think and how we educate. It charts a course toward a post-formal education philosophy based on the most advanced developmental psychology and education research—as a foundation for educational futures. … If higher order, more complex forms of cognition do exist then how can we better educate children and young people so that more mature forms of reasoning appear at the appropriate life stage?...Put simply, we cannot solve tomorrow's problems with yesterday's thinking."

Jennifer Gidley is well equipped to assume this formidable challenge. She is an Australian psychologist and educator at the University of Technology, Sydney, and President of the World Futures Studies Federation, a UNESCO and UN Partner. Her speaking and research collaborations span many countries including Australia, Europe, USA, Middle East, and Asia, and she serves as a Fellow at the Center for International Studies and Research in Paris and at the Botin Platform for Innovation in Education in Spain. Her previous books include *The University in Transformation*, *Youth Futures*, and most recently *The Future: A Very Short Introduction*.

She is not only a theoretician, philosopher, historian, scientist, artist, poet, and sociologist but also an innovative practitioner. Creativity is her hallmark. Early in her career, she founded a modern, creative version of a Rudolf Steiner School in rural Australia, where she taught for ten years. Of this experience, she writes:

> I knew learning could be otherwise. As a responsible participant in their (and my) joyous learning of every imaginable subject through stories, drawing, painting, singing, movement, drama, music, poetry, mythology and play, I have guided numerous children from the age of five or six to puberty. And perhaps as a surprise to many mainstream teachers, the children also became literate and numerate in the process. But instead of just developing a narrow, functional literacy, they developed rich and broad literacies. They learned to read for meaning, to write creatively, to share, to respect nature, to imagine worlds beyond their immediate one, to have social confidence, a passionate love of learning and the courage to be the ones to change the world.

Perhaps an apt subtitle for this path-breaking work is her phrase, "Megatrends of the Mind," since the main thesis is that human consciousness and cultural evolution encompass several stages. While she does not go so far as to claim, as did Haeckel, that ontogeny recapitulates phylogeny, she draws on the work of many philosophers, sociologists, historians, educators, and scientists who have promoted this idea. The title of the book, *Postformal Education*, derives from the work of the educator Jean Piaget, who in the mid-20th century identified four stages of development, culminating in formal operations; many theorists now recognize additional stages of post-formal reasoning. Gidley also draws on the theories of evolutionary stages from Steiner, Gebser, Aurobindo, Wilber, Bohm, and Laszlo, among many others. The details differ, but they map an evolution through mythic, archaic, rational, analytical stages to an emerging integral, holistic perspective. Successive stages do not totally reject earlier ideas; rather they transcend and include. While the notion that human consciousness and culture have evolved is largely undisputed, the new revelation in this work is that now the evolution allows our active participation in a post-formal, integral, and planetary consciousness.

Gidley argues that our educational models, which she identifies with the mid-18th-century industrial expansion and a mechanistic approach to education, are overly formal and analytical. Now the evolution of human consciousness liberates us to address the complex challenges facing a very different, 21st-century world. While the tools and the theory are available, educators are paradoxically slow to incorporate the research. The message, in short, is: If we are to change the world, we must change our way of thinking. Just as we have moved in the past from pre-modernism to modernism to post-modernism, this book portends a transformation to trans-modernism.

Twenty diagrams in art, science, and spirituality enliven and illuminate the challenging and densely packed ideas dating back thousands of years up to the present and illustrating how many seemingly modern ideas have roots in antiquity. In earlier times these ideas were unexamined and natural. Now the collected research presented in this work enables us to understand the connections. The various stages of consciousness evolution were all necessary to bring us to our modern understanding. In addition, 40 tables summarize concepts and logical connections of ideas from many cultures and bring the text to life. The style, design, and construction of the book model its holistic, integrative content.

In a breathtaking voyage through the past, present, and future, this book synthesizes an extraordinary wealth of research and educational philosophy. It is structured into three sections, each with three or four chapters. Part I frames the book in the context of the evolution of consciousness. Part II gathers the existing research on higher stages of reasoning, revealing links between play, wisdom, imagination, ecology, holism, and love. The book stresses the well-established theory of multiple dimensions of intelligence although most current models of education focus on only one. Drawing on these studies, Part III articulates four core pedagogical principles central to a post-formal model of education—love, life, wisdom, and voice. Based on these four principles, education can prepare young people to become complete and whole individuals, more appreciative of multiple perspectives, more trans-disciplinary and connected.

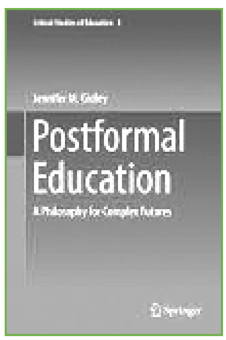
Like a Greek Chorus singing stern warnings in unison, there is now a growing movement inside and outside the academy advocating a new educational model. In the words of Hegel, "The Owl of Minerva spreads its wings only with the falling of the dusk." Philosophy comes to understand a historical condition just as it passes away. The book suggests we are at such a branch point in choosing how we want society and culture to evolve.

There are many nascent movements—integral and integrative learning, contemplative practice, meditation, and spirituality in education—giving intimations of the transformation advocated in this book. Presently, these movements are like separately flowing streams. This path-breaking work by Gidley leads to a convergence of the streams into one river, carving out a path for educating future generations to be more humane, caring, and committed to building a better and wiser world. She also shows that many of our problems may be interrelated. We do not ignore stress and teenage suicides in our schools and colleges, but we set up separate offices to address them. Perhaps the proposed transformation might serve as a universal solvent in an integrated approach to the education of mind, body, and soul.

As the Industrial Age was taking hold, there were counter-revolutions such as the Romantic Movement and the Transcendentalist Movement in the 19th century, each with intimations of an integrative and spiritual approach. Steiner based his philosophy of education on similar ideas, as did the Paideia principle in ancient Greece. Philosophers in the 16th and 17th centuries sparked the Scientific Revolution and the Enlightenment with ideas soon integrated into the general thinking and education. Now we have rigorous research from philosophers, scientists, psychologists, educators, sociologists, all drawn together in this far-reaching book. Perhaps we are on the verge of a new Enlightenment, led once again by thinkers from many disciplines. Can they all be wrong? When we think of the evolution of consciousness and culture, we also think of three great periods of human activity—the Agrarian Age, the Industrial Age, and the Information Age. The author cautions us that the Information Age, despite its potential for greater connectivity, is unlikely to be the harbinger of the educational revolution advocated in this book. Rather we should look at the next emergent level of consciousness as the sign of a coming Integrative Age. Let us hope it does not take decades to blossom. The Information Age could, however, serve as a catalyst to accelerate the transformation.

The words of the poet, Christopher Fry, came to my mind while reading this book: "Thank God our time is now when wrong comes up to meet us everywhere, never to leave us till we take the longest stride man ever took. Affairs are now soul size." Gidley shows that the challenges we face in the world and education are indeed now soul size; she provides us with soul-size transformations. Everyone interested in a better future should read this book. It may inspire us to act before it is too late.

David K. Scott *is a former Chancellor of the University of Massachusetts Amherst.*



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Report from the Online Waldorf Library

Marianne Alsop

The Online Waldorf Library had more than 150,000 site visitors in 2016. In addition to the United States, the United Kingdom, Australia, Canada, India, Philippines, Spain, New Zealand, Russia, and South Africa rounded out the top ten countries from which site visits originated. In the first two months of 2017, Mexico and Malaysia have joined the top ten countries, replacing Russia and Philippines. It is exciting to see where Waldorf education is growing and where the OWL is meeting the need for freely accessible information.

In the latter part of 2016 and early 2017, a number of new eBooks were added, including several in Spanish, one in Chinese, and one in English. Spanish eBooks included *Biografias Para Historia de 8 Grado* by Susan Cook; *La Enseñanza de la Historia* by Christoph Lindberg; *La Importancia de sur Musical* by Cynthea A. Frongillo, and *Crear Espacio para los Ángeles* by Reg Down. In Mandarin, a booklet, *Confessions of a Waldorf Parent*, by Margaret Gorman, became our second offering in this language. From our colleagues at Editorial Rudolf Steiner S.L. in Madrid we now have posted these new titles: *Educación del Niño*, *La Filosofia de la Libertad*, and *La Ciencia Oculta*, all by Rudolf Steiner. Added in English was the eBook version of *An English Manual* by Dorothy Harrer.

Three updated AWSNA/Waldorf Education booklets were added to the website: *Learning to Learn, Windows into Waldorf,* and *Waldorf Education, An Introduction* and two previously published eBooks were redone for better online viewing.

We have also added to our collection of audio books. New audio books were: *The Art and Scence of Teaching English* by Dorit Winter; *Associative Economics* by Gary Lamb; *Developmental Signatures* by Reiner Patzlaff, Wolfgang Sassmannhausen, et al.; *Chapters from Ancient History* by Dorothy Harrer; and *Will-Developed Intelligence* by Patricia Livingston and David Mitchell.

The OWL is adding a large number of issues of the Spanish language newsletter, *Boletin de Metodologia*, translated and published for many years (1971–2002) in Mexico by Juan Berlin. Issues from 1971 and 1972 are now available and subsequent years will follow.

As always, back issues of the *Research Bulletin, Gateways* (Waldorf Early Childhood Association); *The Journal of the Pedagogical Section*, and a number of other international publications are available online in our Journals section.

The Online Waldorf Library welcomes your questions, and we are happy to help you with your research projects.

www.waldorflibrary.org

Report from Waldorf Publications

Patrice Maynard

The Research Institute for Waldorf Education (RIWE) has inaugurated a new study into the results of Waldorf education through a survey of its high school graduates. With generous funding from the Waldorf Educational Foundation (WEF), and the Waldorf Curriculum Fund (WCF), which funded the first research over a decade ago, this new round of investigation is being led by Liz Beaven, who has launched the preparatory stages of contacting Waldorf schools, developing forms for gathering information concerning graduates, and setting up tools for collecting data. The survey instrument is also being revised for maximum use of information about the value of Waldorf education in the lives of our graduates. Lessons learned from the first Survey of Waldorf Graduates will be incorporated into this new instrument of research to increase clarity and insight into the efficacy of a full Waldorf education.

Research into the colleges attended, professional choices made, and values upheld by Waldorf graduates is planned for completion in 2018, making it available for "Waldorf 100," the global celebration of Waldorf education in 2019. The work done on this will be shared by Douglas Gerwin with the International Forum for Steiner/Waldorf Education (formerly the Hague Circle), our international "college of teachers" supporting Waldorf schools round the world, of which he is a member. A new invitation to Waldorf communities to join in the festivities can now be found at www. waldorfresearchinstitute.org/waldorf-100/

Visit the Online Waldorf Library, http://www.waldorflibrary.org/audio-books capably managed by the indomitable Alsops (Marianne and Dave), and made possible by the Waldorf Curriculum Fund (WCF). There are now nine audio books from which to learn while you run, walk, drive, or simply relax. Spanish books and articles too numerous to count are growing in number as we report. Books and articles in English abound there also, along with *Research Bulletins* and *Renewal* articles. All for download, free of charge!

The RIWE website also has a growing number of research articles and papers from the broader world of research in support of the practices in Waldorf education. Rudolf Steiner predicted that science would catch up eventually with the Waldorf methodology, and this is beginning.

Of course, Waldorf Publications continues to make high-quality resources available to the Waldorf community. Coming up soon: *Helping Children on Their Way: Keeping All Children in Our Schools*, by Elizabeth Auer; *The Task of the College of Teachers* by Roberto Trostli; *At Home in Harmony: Teaching Families to Sing Harmoniously* by Meg Chittenden; *Fire the Imagination–Write On! A Guide to the Teaching of Writing in Upper Grades* by Dorit Winter; and more!

About the Research Institute for Waldorf Education

The Research Institute for Waldorf Education (RIWE), founded in 1996 in order to deepen and enhance the quality of Waldorf education, engages in sustained dialogue with the wider educational-cultural community and supports research to serve a wide range of educators in their work with children and adolescents.

The Research Institute supports projects dealing with essential contemporary educational issues such as computers and the effects of media on children, alternatives to standardized testing, physical health and psychological well-being of students, science teaching with a phenomenological approach, the role of the arts in education, and the philosophical underpinnings of Waldorf education.

As a sponsor of colloquia and conferences, the Research Institute brings together educators, psychologists, physicians, and social scientists for discussions on current issues related to education. RIWE publishes a *Research Bulletin* twice a year and prepares educational resources, including collections of eBooks and articles (a growing number of them newly translated into Spanish). Many of these publications are available without charge on the website of the Online Waldorf Library (OWL), a virtual library created and managed by the Research Institute: www.waldorflibrary.org.

In 2013 the Research Institute took over the publications arm of the Association of Waldorf Schools of North America (AWSNA) and re-branded it as Waldorf Publications. It includes resources for teachers and administrators, readers and children's books, collections of plays and poetry, science materials and kits, science and math newsletters, inspirational essays, proceedings of colloquia, and a range of publicity materials about Waldorf education. It also carries books published by the Waldorf Early Childhood Association of North America (WECAN) and the Pedagogical Section Council (PSC) of the School for Spiritual Science, as well as AWSNA's twice-yearly magazine *Renewal*.

As an initiative working on behalf of the Waldorf movement, the Research Institute receives support and guidance from the PSC and financial support through the following organizations:

- Astoria-Stiftung
- Foundation for Rudolf Steiner Books
- Freunde der Erziehungskunst
- Marshall and Margharite McComb Foundation
- Rudolf and Clara Kreutzer-Stiftung
- Rudolf Steiner Charitable Trust
- Sprout Foundation
- Waldorf Curriculum Fund
- Waldorf Educational Foundation
- Waldorf-Stiftung

The Research Institute is a tax-exempt organization and accepts contributions through its annual giving campaign and special appeals.

Summary of Activities Supported by the Research Institute

AVALON INITIATIVE

A think tank for questions of freedom in education

COLLOQUIA (with published proceedings) on teaching:

Chemistry
Computer and Information Technology
English
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Mathematics
Physical Sciences
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ONLINE WALDORF LIBRARY (OWL)

Over 2000 articles and 700 book titles

RECENT RESEARCH PROJECTS

ActionWave study
Alternatives to Standardized Assessment
Computer Technology in Waldorf Schools
Human Sexuality Curriculum
Survey of Waldorf Graduates
Waldorf High School Curriculum Research Projects

RESEARCH BULLETIN

Two issues per year of essays, articles, reviews, and commentaries on educational themes

RETREATS OF THE RESEARCH INSTITUTE

Presentations and discussions exploring contemporary questions related to education

RIWE WEBSITE

Collections of articles and news features on current educational issues

TEACHING SENSIBLE SCIENCE

Three one-week courses on teaching science in elementary grades using a phenomenological approach

WALDORF PUBLICATIONS

Over 400 book titles, plus science kits, publicity materials on Waldorf education

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