Balu H. Athreya · Chrystalla Mouza

Thinking Skills for the Digital Generation

The Development of Thinking and Learning in the Age of Information

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Balu H. Athreya
Professor Emeritus of Pediatrics
University of Pennsylvania – Perelman School of Medicine and Thomas Jefferson University – Sidney Kimmel Medical College
Philadelphia, PA, USA

Teaching Consultant
Nemours- A.I.duPont Hospital for Children
Wilmington, De

Chrystalla Mouza
School of Education
University of Delaware
Newark, DE, USA

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Preface

> Education is nothing if it is not the methodical creation of the habit of thinking.
>
> —Ernest Dimnet

The twenty-first century invites us to retool our thinking skills and habits. It does so because of three different factors, related to the future, present, and past. Our *future*, besides being not fully knowable, will be dominated by technology and human-machine interactions. It will also be characterized by advances in our understanding of how the brain works, which might change fundamental ideas around thinking and learning. Our *present* is already undergoing a major digital revolution in human communication, similar to that experienced with the invention of writing and the printing press. Further, globalization has reached new heights, while polarization on matters related to the *past* is evident. Faith and reason have taken opposite corners, as if they occupy discrete portions of the brain. Once emotion is added to this mix, we often lose clear thinking.

Enamored by new technology, we are likely to forget thinkers from the *past* who wrote about thinking. Philosophers, educators, and statesmen have, in fact, written about thinking since the dawn of modern civilization. This book will review some of their work on how the mind functions, what thinking is, how to develop good thinking skills, and how to avoid common errors in thinking. We need that knowledge more than ever. But we must also understand what current research reveals about thinking, its application to different problems, and, importantly, the role of technology in our social interactions and in enhancing our thinking skills.

All of us think all the time. All of us think we are "good," if not great, thinkers. Are we? Do we know what our blind spots are? Do we know how many of our actions are habits and how many of our ideas were planted in our "heads"? Do we realize that these ideas replay like old tape recorders or digital music players on "shuffle" mode? Most of what we believe are based on customs and conventions; often, we do not fully think through those ideas personally. The rest of our beliefs and opinions are influenced by the beliefs of our parents, our society, the educational system, and several other external sources such as media (e.g., television, Internet, *Twitter*). We need to think through all of these beliefs and opinions for ourselves.

We are immersed in a plethora of information. There are people and organizations who want to influence our thinking with advertisements, "word-sculpturing," "informationals," and propaganda. Because of increasing specialization and the availability of niche media markets, we are also in danger of building a "bubble" for ourselves, accumulating more and more information only on what we prefer to hear. We need "open minds" and "thinking hats" more than ever. In the era of explosive growth in knowledge, it is also impossible for any one of us to be well informed in all fields. We rely on experts for our facts and inferences. Therefore, we need to understand the nature of expertise itself and its relationship to critical thinking.

We are at the beginnings of the Information Age, the third major era in human communication. The future will be dominated by spheres of activity in which humans will have to work with enormous amounts of information and intelligent mechanical devices such as robots. Therefore, we need to know what modern neuroscience is discovering about how the brain functions and how information technology can enhance those functions by helping us learn, remember, and correlate better. In other words, we need to understand how technology can help us *think better*.

The present book is an attempt by a medical educator (BHA) and an educational researcher interested in the use of technology in teaching and learning (CM) to synthesize all aspects of thinking and provide a practical manual for use in the age of information. The purpose of the book is to preserve what is already known about thinking and time-honored methods of thinking skills, lest we forget them in the midst of dazzling new technologies, while also exploring how technology can be applied to enhance our thinking skills.

We have written this book with an eye toward this generation of children who grow up surrounded by technology, accustomed to "quick searches," "multitasking," and social networking. Although the book is an academic text, we have attempted to use a writing style accessible to a wide audience including college students, educators, parents, and other professionals responsible for helping young people think and learn. The book is an equal collaboration between professionals from two distinct fields, which do not normally interact with one another: a medical professional and an education professional. As such, it seeks to provide a balanced perspective on thinking in the age of information that would help those interested in traversing the challenge of growing up digital. We hope that any general reader interested in thinking will also find this book useful.

The production of the book has taken approximately 3 years. During that time, we benefited from each other's expertise, but also the support of other individuals who made this book possible. Balu is thankful to his many teachers in medicine who taught him how to think in the middle of a crisis, even with incomplete information and a human life in the balance, and also in situations where several socioeconomic factors, emotions, and competing value systems play a role in the process of making a decision for a child who cannot make one for himself/herself. A special thanks to Dr. Pamela Arn for her thoughtful comments on earlier versions of this book, as well as to Anna Papafragou for her feedback on chapters related to thinking. Gerald Murray's help with the artwork (Figs. 4.1 and 4.2) is gratefully acknowledged.

Chrystalla is thankful to her colleagues at the University of Delaware who challenge her "thinking" on a daily basis. She is also thankful to her two children, now ages 12 and 14, who are living examples of what it means to grow up in the Information Age and the difficulties faced by youth as they learn to "think" with information. She is also grateful for the support and understanding of her husband and family while completing the writing of the book.

Formally, we would like to thank Jessica Henderson for providing valuable editorial assistance. Most importantly, we would like to thank the editors at Springer, especially Melissa James, and the anonymous reviewers who provided feedback on early drafts of this work and trusted that we would produce a valuable contribution to the field of science and technology.

Philadelphia, PA, USA Balu H. Athreya
Newark, DE, USA Chrystalla Mouza

About the Authors

Balu H. Athreya is an emeritus professor of pediatrics (University of Pennsylvania and Thomas Jefferson University) and has been a lifelong learner and educator. His interest in diagnostic logic, communication with children and parents, intricacies of decision making for medical management, and languages stimulated and maintained his attention on thinking in general. Dr. Athreya has published widely. He is the author of *Pediatric Physical Diagnosis* and *Handbook of Clinical Skills: A Practical Manual*.

Chrystalla Mouza is an associate professor of instructional technology in the School of Education at the University of Delaware. She earned an Ed.D., M.Ed., and M.A. in instructional technology and media from Teachers College, Columbia University, and completed postdoctoral work at the Educational Testing Service (ETS). Her research investigates teacher learning with regard to technology, applications of technology in K-12 classrooms, and teaching and learning outcomes in ubiquitous computing environments. Her work has been supported by the National Science Foundation, the Delaware Department of Education through the Higher Education Component of No Child Left Behind, and ETS. Dr. Mouza is the recipient of the 2010 Distinguished Research in Teacher Education Award from the Association of Teacher Educators and former chair of the AERA Special Interest Group, *Advanced Technologies for Learning*. She serves on the editorial board of the *Journal of Technology and Teacher Education* and provides editorial assistance to numerous journals, conferences, and book publications including the *Journal of the Learning Sciences*, the Annual Conference of the *American Educational Research Association*, and the *Research Highlights in Technology and Teacher Education* book series.

Contents

1 Introduction to Thinking Skills for the Digital Generation 1
1.1 Scope of the Work 2
1.1.1 What Is the Main Message of This Book? 3
1.1.2 How Is This Book Different? 4
1.2 Thinking and Human Brain 4
1.3 Thinking and Memory 6
1.4 Book Content 8
1.5 Significance 10
References 10

2 The Digital Generation 11
2.1 Defining the Digital Generation 11
2.2 Technology and Media Use by Children 0–10 14
2.3 Technology and Media Use by Tweens and Teens 16
2.4 Technology and Media Use by College Students 18
2.5 Learning Preferences of Young People 19
2.6 Guidelines for Technology Use 22
2.7 Main Message 23
References 23

3 What Is Thinking? 25
3.1 Defining Thinking 25
3.2 Types of Thinking 28
3.2.1 Reflexive and Low-Level Analytical Thinking 28
3.2.2 Reflective Thinking 29
3.2.3 Critical Thinking 29
3.2.4 Creative Thinking 30
3.2.5 Convergent and Divergent Thinking 31
3.2.6 Inductive and Deductive Thinking 31
3.2.7 Concrete Thinking 31

3.2.8 Abstract Thinking . . . 32
3.2.9 Analytical and Synthetic Thinking . . . 32
3.2.10 Connective and Substitutive Thinking . . . 32
3.2.11 Computational Thinking . . . 32
3.2.12 Systems Thinking . . . 33
3.2.13 Meditative Thinking . . . 33
3.3 Purpose of Thinking . . . 34
3.4 Main Message . . . 34
References . . . 35

4 The Thinking Process . . . 37
4.1 Background on the Thinking Process . . . 37
4.2 Why We Need to Think on Our Own . . . 38
4.2.1 The Battle Over Our Minds . . . 38
4.2.2 The Influence of Media . . . 39
4.3 Steps in the Thinking Process . . . 39
4.4 Adjuncts to Thinking . . . 42
4.4.1 Listening Skills . . . 42
4.4.2 Language and Thinking . . . 45
4.5 Neurobiology of Thinking . . . 52
4.5.1 Default Network . . . 54
4.5.2 The Limbic System . . . 55
4.5.3 The Reward Circuitry . . . 57
4.5.4 Executive Functions . . . 57
4.6 Basic Modes of Thinking . . . 60
4.6.1 Perception and Response Process . . . 60
4.6.2 Pattern-Making Process . . . 60
4.6.3 Reflexive and Reflective Thinking Process . . . 61
4.6.4 System 1 Thinking Process . . . 61
4.6.5 System 2 Thinking Process . . . 62
4.6.6 Intuitive Thinking of Experts . . . 63
4.7 Main Message . . . 63
References . . . 64

5 Sources of Information for Thinking . . . 67
5.1 Role of Information in Thinking: Why is Information Important? . . . 67
5.2 Locating Information: From Oral History, to Printing Press, to the Internet . . . 68
5.3 Information Seeking Models . . . 72
5.4 Information-Seeking Behavior . . . 75
5.5 Challenges in Navigating the Information Landscape . . . 79
5.6 Information Literacy: Thinking with Information . . . 82
5.7 Main Message . . . 86
References . . . 86

6 Internet and Thinking 89
6.1 Historical and Conceptual Perspectives on Cognition and Technology 89
6.1.1 What Does It Mean to Be Smarter? 91
6.2 Internet and Reading 93
6.3 Internet and Attention 97
6.4 Internet and Multitasking 99
6.5 Internet and Decision-Making 100
6.6 Main Message 101
References 101

7 Sources of Errors in Thinking and How to Avoid Them 105
7.1 Background to Errors in Thinking 105
7.2 Perceptual Errors 106
7.3 Errors Due to Desires and Emotions 107
7.4 Prejudice and Superstition 108
7.5 Evidence Bias Errors 108
7.6 Errors Based on Evaluating Evidence for Claims 109
7.7 Cognitive Errors 111
7.8 Logical Errors 113
7.9 Errors Based on Formal Education 115
7.10 Errors in Thinking Related to Science 116
7.11 Errors Based on Information and Media Sources 117
7.12 Errors Due to Lack of Time 118
7.13 Errors Due to Social Expectations and Pressure 119
7.14 Other Impediments to Thinking 119
7.15 Intellectual Traits Needed to Improve Thinking Skills 120
7.16 Main Message 121
References 121

8 Strategies and Tools for Learning to Think 123
8.1 Learning to Think 123
8.2 Thinking Strategies and Tools 125
8.2.1 Questioning 125
8.2.2 Collaborative Discussions 126
8.2.3 Solving Authentic Problems 128
8.2.4 Brain Training 131
8.2.5 Engaging with Systems Thinking 132
8.3 Memory Supports 132
8.4 Media Literacy 133
8.5 Thinking About Thinking 137
8.6 Artificial Intelligence 138
8.7 Main Message 140
References 141

9 Summary and Future Directions 145
9.1 Book Summary 145
9.2 Strengths of Information Technology for Thinking 146
9.3 Weaknesses of Information Technology for Thinking 147
9.4 Future Directions 148
9.5 Final Thoughts 151
References 151

Appendix: An Exercise in Thinking 153

Famous Quotes on Thinking 157

Selected Reading List/References/Websites 163

Conceptual Definitions 169

Technical Definitions 173

Index 175

Chapter 1

Introduction to Thinking Skills for the Digital Generation

Keep Six Honest Serving Men
Rudyard Kipling

I keep six honest serving-men
(They taught me all I knew);
Their names are What and Why and When
And How and Where and Who.
I send them over land and sea,
I send them east and west;
But after they have worked for me,
I give them all a rest.
I let them rest from nine till five,
For I am busy then,
As well as breakfast, lunch, and tea,
For they are hungry men.
But different folk have different views;
I know a person small-
She keeps ten million serving-men,
Who get no rest at all!
She sends'em abroad on her own affairs,
From the second she opens her eyes-
One million Hows, two million Wheres,

And seven million Whys!

Abstract We think during every moment of our waking time, with or without being aware of it. Ever since the "Golden Era" of human civilization around the fifth and the sixth century BCE, eastern and western scholars have thought about thinking. Initially, the primary purpose of thinking was to deal with the details of everyday living. As social beings, humans also wanted to communicate their thoughts to others. At that early period, communication had two purposes. One was to communicate information. The other was to influence others' thinking and actions. These two purposes are

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still the primary goals of communication. But, in both cases, thoughts come before communication. The human brain, with the use of **language**, is our means to thinking. Previous discussions have approached thinking with attention to two components, the **rational** and **emotional**. But, in the current Age of Information Technology, we must also consider the role of **technology** in our thinking.

1.1 Scope of the Work

We think during every moment of our waking time, with or without being aware of it. Ever since the "Golden Era" of human civilization around the fifth and the sixth century BCE, eastern and western scholars have thought about thinking. Initially, the primary purpose of thinking was to deal with the details of everyday living. Being a social being, humans also wanted to communicate their thoughts to others. At that early period, communication had two purposes. One was to communicate information. The other was to influence others' thinking and actions. These two purposes are still the primary goals of communication. But, in both cases, thoughts come before communication. The human brain, with the use of **language**, is our means to thinking. Previous discussions have approached thinking with attention to two components, the **rational** and **emotional**. But, in the current Age of Information Technology, we must also consider the role of **technology** in our thinking.

Today's youth are born into a world dominated by technology. Novel tools have created new ways of learning, socializing, and communicating that are dramatically different from those of previous generations. Information accumulated over several millennia, for example, is readily available in the "cloud" at the click of a "mouse." Text-messaging, *Twitter*, and social networking sites allow youth to engage in instantaneous communication. A recent study conducted for Common Sense Media using a nationally representative sample of youth ages 8–18, indicate that American teenagers (13–18-year-olds) spend an average of 9 h a day using electronic media, excluding time spent at school or for homework. Tweens (8–12-year-olds) use an average of about 6 h of media every day (Rideout, 2015). This unprecedented use of electronic media has raised a number of concerns and feverish debates among academics, educators, medical professionals, and the public. This debate has become quite polarized, often pitting media proponents against media skeptics.

There is no question that the rise of electronic media and the Internet have created new demands and new possibilities. There is a great need for the digital generation to learn how to organize and process the vast amount of available information, think critically, and turn information into practical knowledge easily accessible for decision-making. There is also an urgent need to help the digital generation consider the advantages, constraints, and problems of electronic media.

Like previous types of technology (including the book), all new technologies come with their own advantages and disadvantages. And, they do not exist in isolation. The effects of the technology on the individual and the society and vice versa

cannot be known fully yet. As a result, current and future generations of youth must keep an open mind and be prepared to think critically about the role and impact of new and emerging technologies. They have an unprecedented opportunity to enhance their thinking skills through technology.

Our brain evolved originally for "fight or flee" response. The reasoning and judgment-making portions of our brains are new accessories ("apps") which evolved more recently. We have to acquire, develop, and maintain these new "apps." Current generations of youth are growing up with new sets of learning experiences and external influences. In the process, it is easy for them to forget or ignore several strategies in critical and creative thinking developed over centuries. We, the authors, feel a responsibility to share those fundamental and fruitful ideas from the past with the digital generation. We also wish to show how technology can and should be used to improve thinking and learning and provide youth with a repertoire of thinking skills that can be used across media. In other words, we seek to communicate that the digital generation must learn how to become *reflective learners* and not simply *reflexive responders.*

1.1.1 What Is the Main Message of This Book?

The rise of technology has resulted in new ways of searching and communicating information among youth, often creating information "overload." Yet, we are still at the beginning of the information age. We do not know how the new technologies will affect the ways that young people learn and think. There are plenty of warnings about the dangers of information technology (Carr, 2011). But, there is also enormous potential for technology to aid human thinking. Rather than taking a polarized perspective, this book will synthesize the state of knowledge related to thinking, as well as the interactions between thinking and technology. It will also provide strategies for helping young people cultivate the thinking skills required to navigate the new digital landscape. The key messages and recommendations of this book include:

- Learn about thinking in general and its pitfalls
- Learn to sort and organize useful information
- Make time to think through information
- Think critically through information
- Construct knowledge out of information
- Learn about external factors which influence thinking and decision-making, particularly media and digital tools
- Learn to develop individual values by reflecting on your own experiences
- Be aware of pitfalls generated by technologies
- Learn to use technology to improve thinking skills
- Learn to think about thinking

1.1.2 How Is This Book Different?

This book is oriented to young learners growing up as members of the digital generation. Educators, parents, and policy makers worry that the current generation of students are deluged with too much information and too many distractions. They are concerned that the arrival of the information age will jeopardize students' ability to acquire, collate, and evaluate information—in other words, think critically and construct knowledge out of information.

This is not really a new problem. In classical traditions, such as those of India and Greece, clerics and philosophers alike worried that written words would jeopardize students' ability to memorize information and think critically. An ancient Sanskrit rule says: "Say thousand words; but do not write even one." Similarly, Greek philosopher Socrates worried that students might be able to obtain information from written words, but be unable to think critically about the information. In fact, he thought that reading from books might lead to superficial, false knowledge and "empty arrogance." As a result, Socrates did not like written words (Wolf, 2007). We now know that he was wrong.

The current generation of "technology-assisted" learners, often called the *digital generation*, somewhat resemble the "book-assisted" learners that Socrates worried about. Students of the digital generation tend to learn from images, sound-bites, and rapid summaries. They tend to skim through information and demand instant answers. Available research indicates that this generation of students tends to "multi-task", seek instant access to information, and spend little time in analytical thinking (Powers, 2010; Rideout, 2015).

Since educators are concerned that students growing up in this environment might forget or ignore all the well-known impediments to clear thinking, we review available classic literature on thinking in general, impediments to thinking, common errors in thinking, and well-tested methods of thinking skills. We emphasize the importance of reflective learning. Since the available store of information in the Internet era has pockets of biased and unverified information, and sometimes even dangerous information, this book focuses on several key topics of future importance. They include: how electronic media affect thinking, how electronic media are used to influence and bias thinking, how we can support thinking, how we can promote media literacy, and how technology can be used to improve thinking skills.

We, as educators, are concerned about the way that media are shaping students' worldview. We are also aware that technology is altering how we learn and think. But, at the same time, we are excited about the enormous potential for technology to aid human thinking.

1.2 Thinking and Human Brain

Writing and learning from written words did not come naturally to the human brain (Diamond & Lee, 2011; Wolf, 2007). It took several centuries for the human brain to evolve and adapt its structures and networks to this uniquely human activity. Will

the neural networks developed over the past two millennia be useful in the new learning environment? Or, will the brain evolve new strategies to adapt to the new world of learning through images and streaming bits of information?

At present, the younger generation learns with technical gadgets and modalities that need manual dexterity, demand quick responses, and give immediate feedback. But, will these technologies delay or hinder the development of reasoning and analytical skills? Current research on the development of neural circuits in children shows that the neural architecture for higher-order cognition is not fully developed until early adulthood and, even then, with uneven development (Blakemore & Chaudhury, 2006; Shaw, Eckstrand, & Sharp, 2007). Myelination (*insulating sheath*) of nerve fibers and synaptogenesis (*formation of new connections between nerve cells called neurons*) play a major part in the development of brain functions. Myelination increases the speed of transmission of electrical impulses from neuron to neuron. These processes are completed in the sensory and motor areas of the brain in infancy whereas they continue into adolescence in other areas of the brain.

During early development, new synaptic connections between neurons form rapidly resulting in high synaptic density per neuron. After reaching a steady state, synaptic density decreases during the process of synaptic pruning. This varies between different regions of the brain and in different species. The stage of rapid formation of new synapses (synaptogenesis) is correlated with periods of rapid learning. Depending on the experiences, frequently used connections are later stabilized, whereas connections that are not utilized are pruned out. This pruning process in the prefrontal area of humans continues well into adolescence and early adult life (Blakemore & Chaudhury, 2006).

The adolescent mind is still curious, but has not developed control over the reward-punishment system and thus potentially lacks the ability to judge and act safely. It seeks novelty and, in the process, faces risks. If properly used, dealing with risks become life's lessons. The plasticity of the developing brain makes it possible to learn from experience, which in turn improves thinking skills.

Therefore, the questions we have to ask are: Can we enhance the formation of new connections in the brain during critical periods through the appropriate use of technology? How can we make better use of the plasticity of the developing brain using technology? Can we gainfully engage the novelty-seeking aspect of the adolescent brain by using technology?

Higher order cognition or the executive functions of the brain include abilities to control impulses, focus on a problem with sustained attention, think creatively, assign priorities, make proper judgments, and plan a course of action. These functions depend on the development of neural networks, which connect the sensory, motor, emotional, and rational parts of the brain. Many of these networks continue to develop and mature into the second decade of life (Blakemore & Chaudhury, 2006; Shaw et al., 2007). We need more research to understand how technology might influence the development of these neural connections.

We also need to understand more about the ways in which technology and the Internet can facilitate the developments of these functions in young learners. We know that the period of new synapse formation is the time that children learn

most rapidly; the period of synaptogenesis coincides neatly with the child's learning curve. Recent studies show that certain functions of the brain can be improved with the use of "computerized training" using hybrid computer-non computer programs, special "tools of the mind", and classroom curricula (Diamond & Lee, 2011; Pascoe et al., 2013). Recent efforts in treating adolescents with risk factors for psychosis, for example, show that cognitive therapy using video games and other devices may be able to facilitate the development towards a more normal trajectory (Insel, 2014).

In this age of information "overload", how do we teach students to seek useful and relevant information, verify its reliability, relevance, and value? How can we teach students to organize the information and show how transformation of information can lead to usable knowledge and practical wisdom? How do we teach thinking skills to the digital natives, who use their time "searching" and "texting"? In this age of multi-tasking, how do we teach them to stay focused and problem-solve? And, how can we leverage access to digital tools that help students develop and enhance thinking skills?

There is a paucity of courses in thinking skills in schools and colleges. Even in medical education, competency in knowledge, technical skills, and attitudes are emphasized, but not reasoning skills. Instead, reasoning is learned as one goes through training by observing clinical teachers and through personal experience. Boostrom (2005) points out that this lack is due to an inability to define and arrive at a consensus about what thinking is, what its attributes are, how it should be taught, and who (which department) should teach it.

All of us can improve in our thinking skills, and fortunately, these skills can be learned. In a report on their study of reasoning skills in graduate students in chemistry, psychology, medicine, and law Lehman, Lempert, and Nisbett (1988) pointed out that people intuitively use rule-based thinking in their daily life. Examples of such rules include rules to think about causality, generalize from prior experience, assess the validity of arguments, and assess evidence that helps study participants make decisions in everyday life. The authors also showed that these rules, when taught, do improve thinking and problem-solving skills.

1.3 Thinking and Memory

Socrates and eastern scholars were concerned that written books would be harmful to memory formation. Though written works do not destroy memory, they do decrease the need for it; books often serve as references that we can consult when our memory fails us. Computers take storage to another level. Computers can store information far better than humans. Not only they can store more facts, but they can recall these facts in a fraction of a second and without ever forgetting them. They can also correlate vast amounts of data. Given this available technology, why should we use our brain like a "filing cabinet"?

The benefit of the written word and books is that the brain needed less territory and energy to store memory. This decreased need probably allowed the brain to develop its correlative and analytical functions (Wolf, 2007). The other advantage of written words is that accumulated knowledge could be transmitted to the next generation. Clearly, the arrival of written words was one of the major events in the history of human communication and learning. The next major event was the arrival of information and communication technologies, particularly the Internet.

With information technology, we can store more information in less space than in books. We can look for correlations and patterns with simulations and complex calculations. However, information is not knowledge. By focusing on more and more information and looking at moving images and disappearing screens, are we losing our ability to stay focused and think through a problem? Are we losing the ability to analyze and synthesize and form new knowledge?

The answer to this last question appears to be "yes" and "no." The current generation of youth accesses information predominantly through the Internet by skimming, looking at different leads without necessarily reading them with care, and moving quickly to other linked sites. These distractions are not conducive to sustained attention, which is so necessary for deep thinking. Studies show that youth in the current generation cannot stay focused on a given task and are weak in analytical and critical thinking habits (Greenfield, 2009). At the same time, studies also show that children's ability to think analytically and creatively and to stay focused can be improved with the use of computer technology. Working memory, which is an important component of creative and analytical thinking, can be enhanced by specially developed computer programs (Diamond & Lee, 2011; Pascoe et al., 2013).

It is also known that excessive reliance on technology may lead to diminution in human skills. For example, it is now documented that airline pilots are losing some of their piloting skills because of excessive reliance on the automatic flight control system (Pasztor, 2013). Whereas automation has brought enormous safety to air travel, some of the recent accidents have been attributed to loss of the ability of pilots to detect problems and take manual control of the plane.

In medicine, it is well-known that with the advent of new technologies, clinicians have lost some of their abilities to examine patients and recognize problems. For example, in one study, 88 medical students and 453 physicians in training (internal medicine and family practice) were asked to listen to recordings of heart sounds of patients with 12 common and important heart problems. Only one fifth of these sounds were correctly identified by the trainees. There was no significant improvement over the period of training (Mangione & Nieman, 1997). This problem is, to a large extent, related to over-reliance on the specialized imaging studies and ultrasound, which are easily available.

But, this technology also brings incredible affordances. The future may be dominated by listening devices that will accurately detect heart murmurs with 100 % accuracy. Such devices are already available. Instead of wondering whether he or she missed hearing a murmur, future physicians with this technology could spend more time using the retrieved information to make a diagnosis.