

## Critical Thinking Skills and Best Practices for Cyber Security

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### ABSTRACT

This research work focuses on critical thinking and its impact on cyber security. This research is based on two strong premises about critical thinking viz., (1) critical thinking skills outsmart the malicious attacks in cyber security and (2) cyber intelligence is inter twinned with critical thinking. The 21<sup>st</sup> century Bloom's taxonomy is visualized from two broad angles' viz., (A) how it is applicable at different levels of current cyber security education system and (B) its impact on the cyber security professionals. Outlined a professionals' look towards cyber security; underpinning the need for CT and cyber security education. Presents a strong mapping between critical thinking life cycle and different phases in cyber security. Finally suggested few guidelines for best practices for improving the cyber security skills at modern corporate arena.

**Key Words:** Critical thinking, Cybersecurity, Emergency and disaster management, Human thinking process, Risk management

### INTRODUCTION

Ever since the human evolution, the human thinking (HT) process is highly subject to its ability towards clarity and rationality. Clarity refers to an in-depth understanding and minute details; and rationality is a human quality reasoning based on a particular logic and reasoning. From a purely psychology and societal perspective this clarity and rationality are two human in-built qualities which lead human towards critical thinking (CT). In one way, CT is defined to be an in-built human ability to improve thought, belief and expectations. In academia CT skills are slowly become essential factor for both learning and development; aptly applicable to this digital era.

The traditional HT is precisely thinking ability from past generation to the present time. HT has two broad agenda: (1) traditional thinking basics is permeated based on certain mindsets, models, decisions and analysis and (2) conventional thinking is general expectation of the people based on what is common at a given specific time in a specific culture. This research clearly demarks, the HT from two different schools of thought viz., academic and corporate perspectives. Around the world CT has been channelized from these two different schools of thought.

In corporate world with digitization process, CT plays vital role in real world problem solving and working through many organizational issues. The challenge at modern academics and corporate world is shifted towards communication and consistency of their students (or employees) in three specific directions: CT, information literacy and quantitative reasoning. This research focusses only on CT. In modern digital era networking and Internet technologies have revolutionized the communication methods; by drastically shifting the HT and communication process to a higher level knowledge domain. Unfortunately it also start presenting significant number of challenges. Finally tune the world towards knowledge economy making information skills as paramount for an individual success. The above challenges includes implementation of effective CT, information literacy and qualitative thinking; revamping the national economy into an information economy.

On the other hand emergency and disaster management (EDM) was in existence since ages in dealing with humanitarian aspects of emergency. Communication and group coordination are in particularly vital in EDM in view of their incidence occurrence being highly unpredictable. The digital revolution has brought new EDM to this world, namely cyber security (CS), with reference to digital thefts and crimes. CS is basically a cyclic loop among the preparedness, responsiveness, recovery and mitigation. CT has become an essential and adoptable approach in all emergency situations due to its unique reasoning capability. For example, within EDM, CT has been a source for several emergency management people, such as First Responders, Public Safety, and Security Personnel to [2][33]:

- Determine where their aid is most immediately needed to have the critical thinking skills to analyze problems, identify and evaluate options, and explain choices based on solid reasons and evidence.
- deal in an unbiased and effective manner with people who may be highly emotional
- defuse threatening situations legally, swiftly, and with minimal negative fallout
- evaluate options, anticipating potential difficulties and reasonable solutions
- objectively gather, document, and interpret information and evidence
- plan, evaluate, and implement effective public safety and security measures
- Explain threats, options, plans, and progress to senior leadership and coworkers.

In the same vein technology/digitization brought certain essential and adoptable approaches in many emergency situations, such as database hacking, network vulnerability, injection of malware, under the scope of CS. Slowly the corporate digitization of processes, services and storage, have brought CS education under its core managerial function. In particular CT in CS is not only useful in handling/dealing with software/digital vulnerabilities but also help cope up with cyber thefts and crimes. The past research has also thrown light on use of CT in CS advantage in many ways as [1] [3] [7]:

- To apply quantitative and algorithmic skills
- To make high stakes decisions about data/CS
- To assess and manage technology risks
- To plan, evaluate, and implement CS measures
- To respond to CS breaches/threats
- To identify and integrate the latest CS intelligence
- To adapt systems to the constantly changing technological environment
- To lead the deployment of prevention and technology recovery plans
- To explain threats, options, plans, and progress to senior leadership and coworkers

These are just based on CT and its applications while addressing corporate CS from the technical responsibility perspective. Invariably CT has also its impact on several HT process (non-technical) issues. For example, based on its functionality CS management must comply with following eight basic ways [3] [4]:

- **Comprehensive:** CS managers needs to consider and take into account all

software/hardware vulnerabilities, at all process phases, all stakeholders and all impacts relevant to cyber disasters. CS professionals need to consider and take into account all sorts of digital thefts and software vulnerabilities, which impact the corporate security breach.

- **Progressive:** CS managers must anticipate future disasters and would like to take preventive and preparatory measures to build disaster-resistant/disaster-resilient communities. Cyber thefts or crimes can take place across databases, networks and file systems; making organizations be alert in using certain preventive measures based on risk management (RM) principles and practices.

- **Risk-Driven:** The underlying principle of CS management is the sound RM. Under these RM principles, there is some optimism towards avoiding any possibility of hackers and cyber criminals.

- **Integrated:** CS principles are mostly composed of network/information security. Thereby the EDM managers ensure unity of effort among all levels of the organizational management, government and all elements of a community.

- **Collaborative:** Any CS and forensic investigation is a team-based effort, needs a strong group collaboration technique. Thus demands a strong and sincere relationship among inter-group and intra-group individuals.

- **Coordinated:** Within CS area a good coordination is vital to address any particular security breaches; this can be between individuals as well as systems (such as clients and servers).

- **Flexible:** Though there are certain procedures and practices in force for handling CS cases, at times one needs to be more flexible in their approach. For example, when working on network security breaches and during network vulnerabilities, CS investigators need to be

more flexible in shutting down the entire organizational network.

- **Professional:** To cope up with everyday evolving new CS breaches, it is almost mandatory to exhibit certain amount of professionalism; through certain knowledge-based approaches based on education, training, experience, ethical practice, public stewardship and continuous improvement.

Thus CS needs to comply with these qualities with respect to digital components or assets. Before one goes further, first extract the essence needed to derive from Bloom's CT taxonomy and its relevance to CS.

## LITERATURE REVIEW ON CRITICAL THINKING & BLOOM'S TAXONOMY

CT has been a serious research topic for many researchers in various fields like social science, psychology and computer science. In each of these fields, CT and its interpretation vary according to its specific real-world problem-solving capability. This research work is limited to CT and its involvement in CS. First familiarize with few definitions, before we move on to the core topics.

In general, freely available entities for human constitutes "data" do not convey immediate meaning; such as different age groups of children living in a city. Visualizing such data in a useful/meaningful way constitutes "information"; such as 0 to 10 year/11 to 20 year/above 20 year age groups. Once human processes this information in a particular context or a real-life application, becomes "knowledge"; such as need for the construction of primary/high schools or community colleges/universities. Similarly, in an object "car" its different parts constitute "data" knowing the functionality of these parts such as breaks, steering wheel, and accelerator constitute information. Driving or using car in a specific context or

situation, such as driving a car to a particular place such as shopping mall/movie theater demands “knowledge”, comes up with principles/processes such as driving, parking etc.

Thus knowledge is always a specific context specific, cannot be for a general use. Computer process ‘data’ into ‘information’, where as human mind due to its inbuilt cognitive faculties: perception, consciousness, thinking, judgement, language and memory; is capable of processing or converting ‘information’ into ‘knowledge’, for real world problem solving. HT is a continuous activity in processing or strengthening the relations between “stimulus” and “response”. CT being part of HT process generates knowledge can be visualized from different ways. CT is thus the ability to reflect on and so improve, human thoughts, beliefs, and expectations; most mod the times this is a combination of several skills and habits as [37]:

**Curiosity:** A strong desire for generating knowledge and understanding its purpose. Curious people are never content with their current understanding of the world, but are driven to raise questions and pursue the answers; is an endless activity.

**Humility:** This is a “recognition” process, here knowledge is limited to your own understanding; which is not fully validated; somewhat closely connected to curiosity. In case, if you are arrogant and think you know everything already, then you have no reason to be curious. But a humble person always recognize the limitations and gaps in their knowledge; making him more receptive to information, better listeners and learners.

**Skepticism:** This is a knowledge generation process with suspicious attitude toward what other people say. Skepticism means such person always demand evidence and do not

simply accept what others tell him. Skepticism has to be inwardly focused as well, making equally skeptical of his own beliefs and instincts as you are of others’.

**Rationality:** This is a specific HT process generate formal skills of logic; which are indispensable for critical thinkers. Skepticism keeps you on the lookout for bad arguments and rationality helps you figure out exactly ‘why’ they are bad. Rationality also allows you to identify ‘good’ arguments when you see them, and then to move beyond them and understand their further implications.

**Creativity:** This is a ‘knowledge’ generation process generate human ability to come up with new combinations of ideas. It is not enough to just be skeptical and knock the holes in every argument that you hear. Sooner or later human expected to come up with his own ideas, solutions and visions; requires a creative and independent mind, but he is also capable of listening and learning.

**Empathy:** This is a new ‘knowledge’ generation process: The ability to see things from another person’s perspective. Often people talk about CT as though they are solitary explorers, forging their own path through the jungle of ideas without help from others; is not true always. Real CT means one constantly engage with other people, listen to what they have to say, and try to imagine how they see the world. This way of seeing things from other’s perspective human can generate far more new ideas, than his own.

These six skills basically generates knowledge from given information. Within the CS, the impact of HT process plays vital role in realizing a security breach. The most of modern firewalls are designed or programmed according to hackers’ attitude and thought process. Unfortunately the

hackers' thinking process is not unique at any given situation. Till the security breach occurs, the versatility and the thinking process of a "hacker" is a mystery and very difficult to identify and qualify him/her along with his/her thinking process.

Several researchers in past attempt developing theories on HT process with CT component. One such seminal work is precisely the Blooms taxonomy, play a major role in understanding and analyzing HT process/reasoning, associated with educational activities. The CT research work on different ways of HT process and its application is described below.

### **BLOOM'S TAXONOMY AND THE EDUCATIONAL ACTIVITES**

The basic premise of CS education is to develop certain CT skills which can help outsmart the hackers thinking capabilities; especially so in handling technology based problem solving. The past research address several ways of looking into the motivation and conceptual understanding behind CT or general problem-solving skills [22]. According to Mayer CT involves in development and growth of thoughts, analysis, questioning and reflecting on realities and experiences and applying them into the problem solving [3][21]. Similarly Brookfield defines CT as a survival ability which helps facilitate peoples' paths through their lives [23].

The seminal work of Benjamin Bloom established a solid framework for categorizing cognitive thinking educational goals and objectives into a hierarchical framework based on a level of CT. The current work narrates the Bloom's Taxonomy model of six levels of difficulty and complexity of intellectual or cognitive skills

along with its impact on CS education. presented in Table 1 [24]. This framework conveys: Each stage of learning is a prerequisite for the next stage and therefore mastery of a given stage of learning mandates mastery of the previous stage; which is also the primary goal of CS education as well; especially so in handling cyber thefts/crimes.

The Table 1 below identifies six levels of Bloom's cognitive learning arranged from lower-order to higher-order of learning domain; starting from the simplest to the most complex in an in-depth coverage of each category: knowledge, comprehension, application, analysis, synthesis, and evaluation. These learning domain descriptions along with their logical thread to CS is presented. This process determines that students must master all steps in its recommended order to develop and master CS skills. During 1990s CT research start focus on certain principles and progression process. Eventually several models of critical thinking with explanation and validation of the stages of inquiry, have been developed by Bloom in support of critical reasoning skills [25] [26]. The way people slowly bend towards CT, clearly witnessed by those involved in passing through several identifiable and commonly experienced phases; contributing towards advanced reasoning skills.

Learning Domains	Description	Logical Threat to Cyber Security Education
<b>Knowledge</b>	The remembering of previously learned material; this involves the recall of a wide range of material, from specific facts to complete theories.	In all of the cyber-attacks, one thing is worth noticing: The pattern of hacker thinking process and its implementation.
<b>Comprehension</b>	The ability to grasp the meaning of previously-learned material; this may be demonstrated by translating material from one form to another, interpreting material (explaining or summarizing), or by predicting consequences or effects.	In cyber security accessing, monitoring and management, play a vital role. Cyber security education teaches the ways of detecting software or tool used by hackers, in each case. This will help preventing the fourth coming cyber incidents.
<b>Application</b>	The ability to use learned material in new and concrete situations; this may include the application of rules, methods, concepts, principles, laws, and theories.	It is almost impossible to predict or guess, the new viruses and new tools used by hackers. The length of the time, the hacker is in the network or holding a database reveals, gives us a clue of what application software he has/she has used for committing crime.
<b>Analysis</b>	The ability to break down material into its component parts so that its organizational structure may be understood; this may include the identification of the parts, analysis of the relationships between parts, and recognition of the organizational principles involved.	Cyber security education teaches certain methods of investigation. Each method is followed by a sequence of steps to be followed; for a clear analysis.
<b>Synthesis</b>	The ability to put parts together to form a new whole; this may involve the production of a unique communication (thesis or speech), a plan of operations (research proposal), or abstract relations (scheme for classifying information).	With new type of cyber thefts, arising in every minute/hour around the world; the synthesis aspects of cyber security is very difficult. A good Communication among the pairs such as Employees-Management, Customer-Company, Project Leaders-Team members, etc., almost set right the operational clarity, which establishes the information security.
<b>Evaluation</b>	The ability to judge the value of material for a given purpose; The judgments are to be based on definite internal and/or external criteria.	The cyber security education, the evaluation of a cyber-theft, is highly subject to critical thinking aspects of specific software/hardware usage.

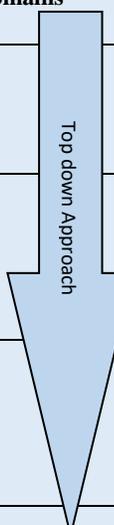
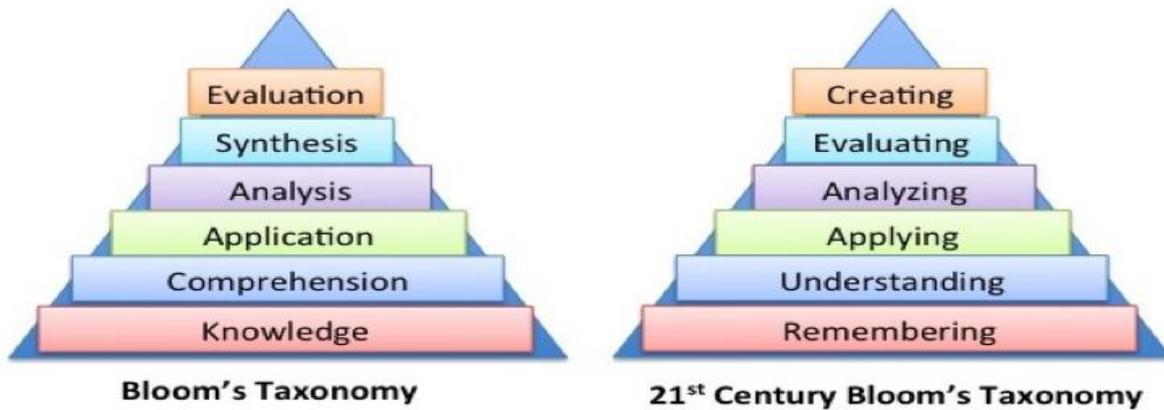


Table 1. The Cognitive Domain and the Development of Critical Thinking Skills  
 Source: Bloom et al. Taxonomy of Educational Objectives, 1956.

In recent decades, the Bloom taxonomy model has been altered several times, by several authors in several ways. Anderson and Krathwohl revised the Bloom's Taxonomy

framework where the knowledge was replaced by Remembering, Synthesis by Evaluating, and Evaluation by Creating, as presented in figure below [27].



Bloom Taxonomy Model and 21<sup>st</sup> Century Bloom's Revised Taxonomy Framework  
Source: Anderson and Krathwohl [27].

Many authors implemented the 21<sup>st</sup> Century Bloom's taxonomy framework to develop techniques and classroom activities that advance CT throughout six levels of cognitive progression [28][29]. Most of the CS research is also very much related to cognitive thinking of hackers. Many researchers also argue that human do not develop CT skills solely from a lecture, assigned readings or by taking exams [30] [31]. In order to pick up CS skills, modern corporate employees must be guided through above six-step Bloom's Taxonomy framework. Initially employees are expected to master the discipline's basic concepts, terms and methodologies. Once employees' memorize and advanced understanding of them, higher levels of CT skills can be developed best in a setting patterns. In particular to CS, it is with respect to hackers' dialogues, ideas, approaches, patterns recognized.

Corporate work environment is quickly evolved beyond remembering, retrieving, recognizing, and recalling relevant knowledge. The familiarity with databases, organizational network environment and their vulnerabilities once controlled by a skilled working group of employees, not by the management people. At this point, there

are two broad questions to be addressed: First, is this group controls of the entire organizational CS? Second, how do management supervise and manage the organizational information technology and CS? Unfortunately there is no straight forward answer to both these questions.

This research is attempting to address the role of CT in a CS environment. Modern corporate's CS is every ones' responsibility, mandatory CS training to employees should go through different levels, depending on their work nature and usage of work place information systems (IS). CS trainings includes questioning, interpreting, exemplifying, classifying, summarizing, inferring, comparing, explaining, applying, analyzing, synthesizing, and evaluating, organizational information. Employees using various ISs are responsible for their security as well. These elements allow employees' to advance/progress their CT reasoning skills to the highest level of cognitive thinking.

### **CRITICAL THINKING REASONING: A BLOOM'S MODEL APPROACH**

Over all, Bloom's taxonomy is about levels of thinking related to cognitive processes with an affective domain with pertinent levels of behavior. Most importantly these

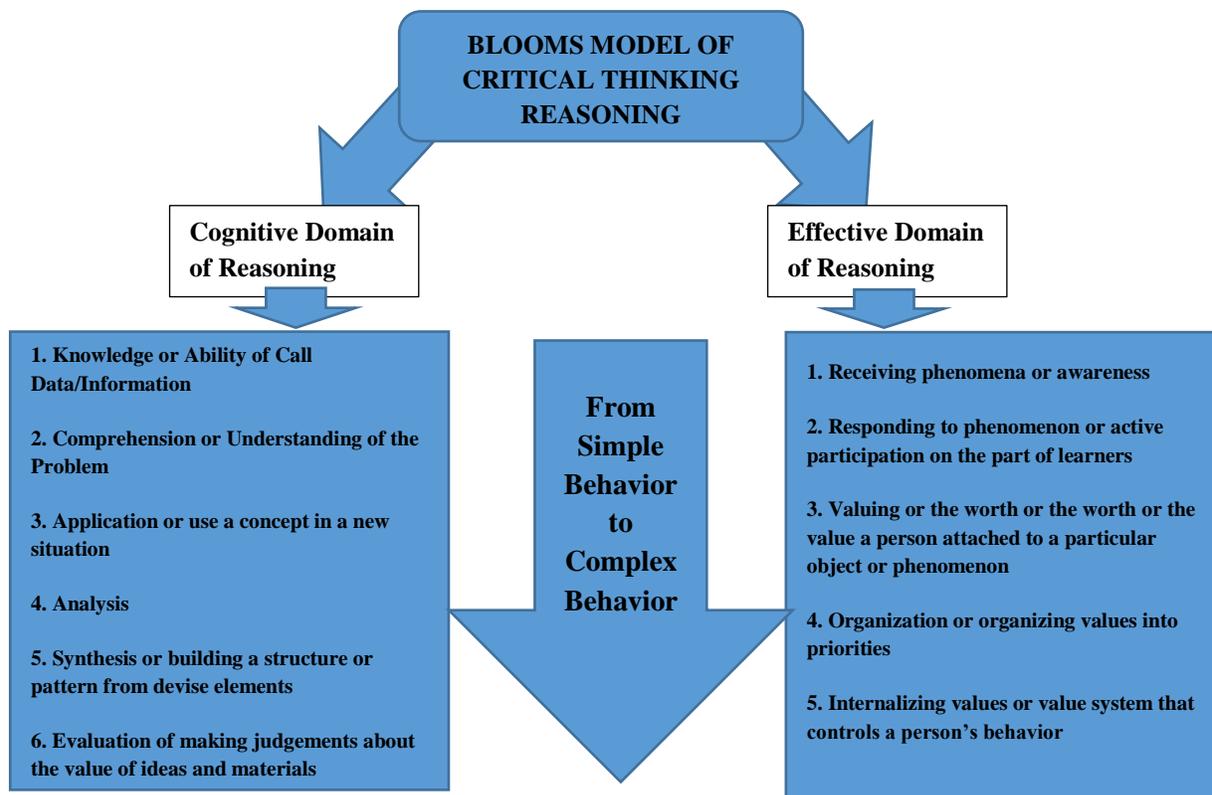
behavior levels, depicts various ways people relate themselves to the phenomena they encounter; in this research it is CS. Thus the constant efforts to improve CT refers to an advancement to a higher level in Bloom's taxonomy; such is an attempt in this CS research work.

Thus most critical thinkers' faith is lies in their power of logic and sound reasoning. If we observe the Bloom's taxonomy in details, one can also observe a systematic reasoning patterns; which are very much in congruence with cyber hackers'. This opens new research direction of looking in to modeling of reasoning's while solving real-world problems; across the field CS. Present here a possible model outlining the Bloom's

reasoning process.

Past research signifies that the development of CT or demonstrate how to improve CT skills with specific curriculum materials or instructional methods have been handful and mostly theoretical without much practical insight [28]. This work throws some light on the practical aspects of CT with respect to CS. A model is thus a precise description with finer details of the concept.

A model of CT reasoning developed by Blooms can be visualized from two perspectives viz., cognitive and effective domain reasoning as shown below, each devoted to theoretical base and the best practices impact.



Within these two domains there are several analogies which are truly applicable to CS education; vital for modern corporate world as following [18].

**Cognitive domain:** This focus is on intellectual skills such as CT, problem solving, and creating a knowledge base. This was the first domain created by the original group of Bloom's researchers. The cognitive

hierarchy spans from 'simple memorization' designed to build the knowledge of learners, to creating something new based on 'previously-learned information'. In this domain, learners are expected to progress linearly through the hierarchy, beginning at "remember" and ending at "create."

As mentioned earlier CS education is not simply about memorization instead 'learning the patterns' of cyber hackers' thinking process; finally ending up with a 'new solution creation', based on "previously-learned threat patterns". Here learners are expected to progress non-linearly due to evolution of new patterns of cyber thefts/crimes time to time; with no universally accepted one solution of one type of cybercrimes/thefts.

**Affective domain:** This affective domain focuses on the attitudes, values, interests, and appreciation of learners. The hierarchy is clearly interlinked with its series of functions such as: receiving and listening to information, and extends to characterization, or internalizing values; and most importantly consistently acting upon them. It basically focuses on allowing learners to understand what their own values are and how they have developed. The affective hierarchy can be described in several ways. In CS education, this affective domain focuses on analyzing criminals' attitudes, values, interests, apart from appreciation of learners; but in a slightly different way. Attitudes of a cyber-criminal is highly non-linear and vary differently in each case. All the risk management techniques are developed so far are based on theft or crime patterns and frequency; with the values vary from basic curiosity to huge financial losses.

Within CS the occurrence of 'cyber indents' are highly un-predictable and will happen at random; though one attempts to recognize

'patterns' of happening. It is thus need to be first internalizing values of value systems that control a person's (typically employees') behavior, that come under domain reasoning. Then it needs to be evaluated for making judgments about the value of ideas and materials, which come under cognitive reasoning.

## **LEVELS OF CRITICAL THINKING IN AN EDUCATION SYSTEM**

CT is expected to help enhancing the academic quality and performance, hence requires at all level of our education system. Rather than relying exclusively on teacher notes or class room time for instructions and guidance, students with CT skills can become more independent, self-directed learners. In order to prepare the people for rapidly changing world of technology, one need to instill an approach based on CT [14]. Most of the modern organizations are complex by default, due to usage of different technologies, various individual thinking processes, apart from business pressures. In order to cater to this complex environment, we need to harp on students training on CT at various levels. Most importantly one need to provide skills that make them to understand IS in which how new technology is operating.

Fast growing digitization revealed one fact: One cannot foresee everything, in spite of a solid good plan. Thus CT is aspect to focus in such a way that, (1) continuously test, (2) review and most importantly (3) feed that learning into organizational evolving plans. Across the modern organizations, every one need to understand and practice flexible management aspects.

According to past literature, there are two core skills of any modern IT professionals are CS and software engineering [14]. First, CS explores, different ways of using technologies, and stay up to date with them.

Please keep in mind certain organizational operations such as project management, process control, supply chain management, configuration management, etc. impacts the security of data or information. The following are the corporate issues which needs CT skills

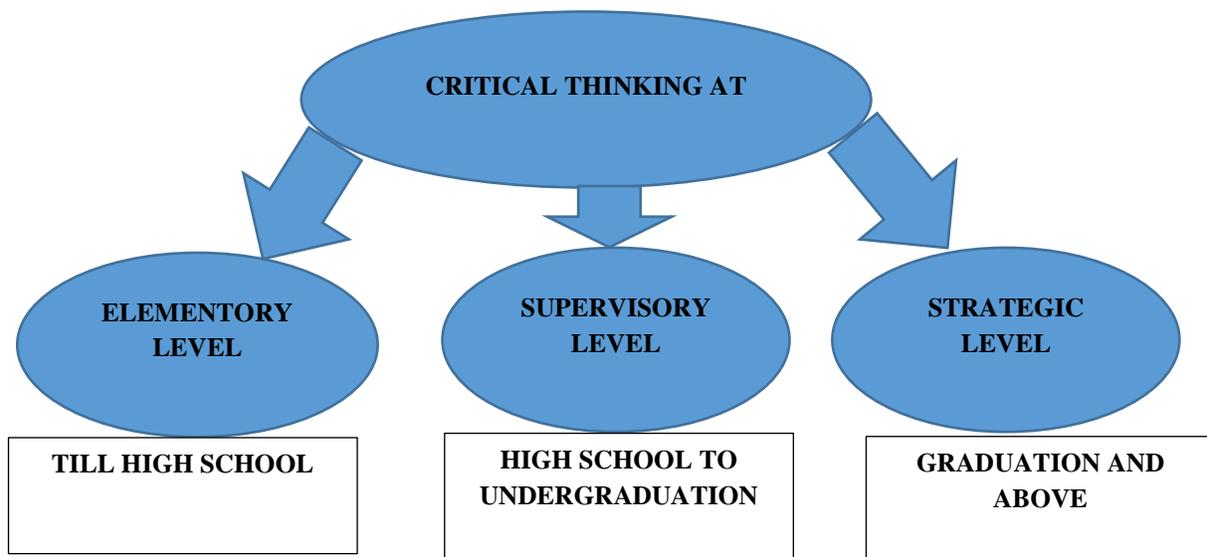
- Employees weaknesses, in particular white color employees
- Attackers' motivations and skills
- Available technologies for defense

Second, software engineering is primarily targeted towards obtaining the organizational needed software either in development or market made purchase mode. Generally this field insists of going through four prominent phases viz., planning, design, implementation, testing and installation; an evolving process. Overall, software engineering acts as an interface between the

organizational business and the external world. The main emphasis here is to establish a model of relationship between the software, the organization it serves and its wider environment.

CT is not pertaining to certain age group, instead applicable to all sections of age. Since this possess the ability to think independently and while being logical at the same time; which is the needed power of students' in this digital era. This research broadly categorized CT at three levels of education as below.

A person's educational level generally determines based on his/her CT ability and its applications. CT skills are highly subject to their specific learning or application aspects, rather than depending on the available resources or data. In a human learning curve it grow through at three different levels as:



#### **ELEMENTARY LEVEL – Till High School**

At this level of CT, one call it as foundation to intellectual growth. Here one needs a close supervision from a teacher/instructor who can inject basics into such tender age. CT training has become increased focus on K-12 education, due to the ongoing demand for

teachers, school administrators, education specialists and leaders [17].

Schools and school districts start hiring the officers, and other education professionals exclusively to teach CT and problem-solving skills. Most of the schools take care of certain

schemes such as STEM, Quant Q, TER-N, CSS etc., schemes to promote CT, at this level especially in the subjects like mathematics and science. These schemes not only improve the CT skills but also promote general reasoning skills. Teachers need positive CT habits of mind if they are to model and nurture attitudes in their students. CT at elementary level are primarily focus on 'thinking ability' in the light of following factors:

- Clarity is an essential component at this age group. This is the first steps in student age
- Logical, is a learning art, necessary at this stage, vital for developing CT
- Rational, is a part of clarity, needed in the early childhood.
- Independent, will make you an independent thinker, a good quality of a critical thinker.

These are need to be coupled with certain actions such as mindful communication, as maturity is a big issues at this level.

#### **SUPERVISORY LEVEL - High School to under graduation**

Motivating high school students' to an under graduate program, is a real challenge to high school counselors. This transition not only give push towards career progress but also teach students' adoptability with supervisors. Young adults have been the driving source in improving country's economy and useful in addressing societal issues such as unemployment, poverty eradication. CT components help supervise more effectively and efficiently in handling this age group students. Quality of this age group thinking is reflected in quality of councilors' treatment. Author calls this 'supervisory' due to its essential need for a 'closed supervision'. This

is a transition period and are thus expected to be a future critical thinker; with a primarily focus on 'thinking ability' towards:

- Career direction/focus, is basically understanding/planning, fourth coming events and make them ready for it
- Attitude improvement, is precisely the observations and deriving the useful conclusions.
- Responsibility improvement, is more attached with integrating the different aspects of the given situations and systematically arriving at a feasible decisions.
- Defining education as part of culture, is a very broad agenda to be installed

This is the most crucial level among three in imposing criteria and intellectual standards for possible CT skills development.

#### **STRATEGIC LEVEL - Graduation and Above:**

The above two levels are more of learning curves and this is an application curve. Where one learns the implementation aspects of CT. This higher order CT skills involve creative thinking, problem solving and strategic decision making; means applying background knowledge to analyze and synthesize the information. CT can be interpreted here as: With less background knowledge on the topic; the more one need to infer, through the capability of reading between the lines. CT at strategic level primarily focuses on 'thinking ability' in the light of following:

- Strategic decision making capabilities
- Connectivity of knowledge to prior experiences
- Improving the leadership qualities
- Self-monitoring of understanding.

- Group coordination and communication skills
- Vision towards improving intellectual and creative thinking
- Capability of organizing information and applying meaningful framework/categories.

## **CRITICAL THINKING AND THE CORPORATE WORLD**

The development of information technology (IT) has undoubtedly brought face-lift to the corporate world, in several directions with future trends. To address tomorrow's technology, one need to move from current mindset of knowing how to apply technology to well understood different situations, to one of being able to think critically about problems, and then identify solutions to unknown as well as familiar technology issues [14]. The past research also addresses the missing of CT component in formal as well as at in-house training programs in a corporate world.

CT is visualize from different schools of thought: Decision making, planning, strategic thinking, etc. CT known as a unique thinking process with its flexible adoptability subject to the considered domain. As a real life model, CT is more than just a concept, up on which one can build successful and efficient problem solving skills; and those skills that prove highly valuable in the workplace and beyond. CT creates an awareness of differing approaches to a problem, so is the ability to assess those approaches critically. It creates appreciation for different worldviews apart from saving time and enhance communication capabilities. For example, the following are some of the benefits of CT skills [14]

- It better controls humans' own learning and empathy for other point of views.

- It entails effective communication and problem solving abilities and accommodate a commitment to overcome our negative ego-centrism and socio-centrism.
- It is important in life, allows us to think creatively – outside the box.
- It enables person to make good decisions in situations of risk and uncertainty as well as in situations required logical precision.
- It can teach a variety of skills that can be applied to nay situation in life that calls for reflection, analysis and planning.
- It gives ability to think well and solve problems systematically is an asset for any career
- It is very important in the new knowledge economy, in a fast-changing workplace.
- It plays a vital role in evaluating new ideas, selecting best alternative solutions, modifying them if necessary.
- It is crucial for self-reflection, it also provides the tools for the process of self-evaluation.
- It is basic foundation of science and a liberal democratic society.

Corporate world got a face lift with digitization process, at every stage during this transition CT is continued and still moving forward. Functionally the role of CT is limited to preserving, retrieving and communication across the organizational of business networks and databases.

## **CYBER SECURITY EDUCATION: AN ACADEMIC PERSPECTIVE**

Over centuries subject fields like mathematics, physics and chemistry do exists in academia and still continue to evolve in main streams; for two reasons:

- A. Due to their ability to formulate a real life problem with compatibility to modern software systems; is scientific viewpoint
- B. Due to economic and societal needs, coupled with acute public (market) demand; is– Social Science viewpoint

The strength of these fields lie in their journey moving from analytical to real-world problem solvers. These fields, initially developed analytically, progressed towards real life applications and finally evolved as software systems; in automating the tasks. The process of fine transition from a sequence of solution steps (for a problem) are translated into machine readable code (call it software system), called digitization. For practical purposes these software systems were (and even now) happened to be user friendly when compared to just a sequence of solution steps. It is like a fast journey from a compiler (or an interpreter) design to a printed circuit board (PCB), and evolved towards voice and speech recognition systems, is a technological evolution. During such technological evolution, CS has been an invisible under flowing water, which recently start flowing into the surface in the wake of data and information security breach.

Fast growing industrial digitization coupled with socio-economic conditions have brought CS education into the lime light; allowing CS education to spread its wings into all levels of academia. This is so mainly due to its CT capability. CS education involves protecting information and systems from major cyber threats; such as application attacks, malware, ransomware, phishing, exploit kids etc. Academic institutions also realize the significance of CS education at their under graduation/graduation curricula; emphasizing CS education as non-linear mix of several domains as described below.

## **CYBER SECURITY: A MIX OF SOCIAL SCIENCE, MANAGEMENT AND ECONOMICS**

Most of the existing traditional approaches in CS has been to use preventive-measure strategies, focused on blocking digital attacks. These preventive-centric measures, are solely concentrated on techniques and measures which can prevent attacks. In view of advanced and motivated threats today, this strategy has changed, which emphasis the defense with creative, stealthy, targeted, and persistent attacks that often go undetected for significant period of time. Therefore the CS education has become an essential component in the modern corporate world, with an added CT component.

Over the years, the evolution of several information systems (IS) and the intra-dependency of modern organizations on these computer based systems have ultimately put the security (of systems) in the cross roads. The security of ISs is inevitably fall under the responsibility of every one across the organization. This responsibility has been viewed from three different perspectives. First, the field of social sciences is basically concern with society and the relationship among individuals. CS is thus directly impacted from this field due to

- **Using ISs:** Differences in individuals use ISs for various “purposes”. Some use it for their day to day work purpose, other use it for evaluating their work performance. Some others use it for implementing and improving their innovative ideas. In either case, it is very difficult to de-mark the use and misuse purpose of ISs.
- **Perceiving ISs:** Given a huge amount of digital data, within a computer based system, different individuals “perceive” it from various schools of thought. Perceiving this huge freely available digital data from different mind-sets, makes data more

volatile, easy for anyone to copy, delete and alter it.

• **Security of ISs:** Different people take information systems' responsibility at varied levels of interest. Though most ISs are available for every employee, but how much of interest one pays for their security, is an open and challenging question for management.

Second, "economics" has been an organizations' backbone, makes technology as competitive force, to modern corporate world, focus on estimating its opportunity cost. It also reveal several ways of maximizing the value and the consequences of technology and its impact on businesses. CS has finally become the bottle neck issues for many organizations; influencing the economic impact of technology on businesses. Microeconomics focus on individual department's ISs and their viability towards that unit's productivity. Macroeconomics is for estimating impact of all ISs prevailing within an organization. CS education is thus become vital form high school level. It is not only inter linked with digital threats/crimes but also inter-twinned with socio, economic and cultural issues.

Managing ISs become bottleneck issue to corporate world, for two reasons: (1) changing technological trends and (2) maintenance of technological processes across organization. CS management process cannot be made unique; it is inter-twinned with individual ISs. Past research on CS education identifies six most prominent fields, with CT as high priority as [15]

- Critical thinking
- Strategic planning
- Leadership
- Empowerment
- Organizational research
- Technology and communication

CT has been the first and main focus that needs to share with the rest. Rapid changing technology and dependency on internet of things (IoT), makes everyone experience a surge in cybercrimes and digital threats. In the midst of this crisis, the United State Government has launched initiatives specifically for cyber security education that are designed to help schools (just like yours) develop the necessary degree programs. The National Initiative for CS Education (NICE), led by the National Institute of Standards and Technology (NIST) in the U.S. Department of Commerce, is a partnership between government, academia, and the private sector focused on CS education, training, and workforce development. Below is a description of each of the seven NICE Framework Workforce Categories which acts as a resource for academic curriculum development for our institutions [16]:

- *Securely Provision (SP):* Conceptualizes, designs, procures, and/or builds secure information technology (IT) systems, with responsibility for aspects of system and/or network development.
- *Operate and Maintain (OM):* Provides the support, administration, and maintenance necessary to ensure effective and efficient information technology (IT) system performance and security.
- *Oversee and Govern (OV):* Provides leadership, management, direction, or development and advocacy so the organization may effectively conduct cybersecurity work.
- *Protect and Defend (PR):* Identifies, analyzes, and mitigates threats to internal information technology (IT) systems and/or networks.
- *Analyze (AN):* Performs highly-specialized review and evaluation of

incoming cybersecurity information to determine its usefulness for intelligence.

- *Collect and Operate (CO)*: Provides specialized denial and deception operations and collection of cybersecurity information that may be used to develop intelligence.
- *Investigate (IN)*: Investigates cybersecurity events or crimes related to information technology (IT) systems, networks, and digital evidence.

### PROFESSIONALS LOOK AT CYBER SECURITY

Today the technological advancement races ever onwards, along with cybercrime is set to grow as criminals take advantage of new exploits; leaving the bottleneck issue as: How do we coop up with cyber data, businesses and transactions, along with increasing cyber criminals? The world economic forum listed cybercrime as, among the top three most likely risks the world face by 2020; is a complex combination of four different loops,

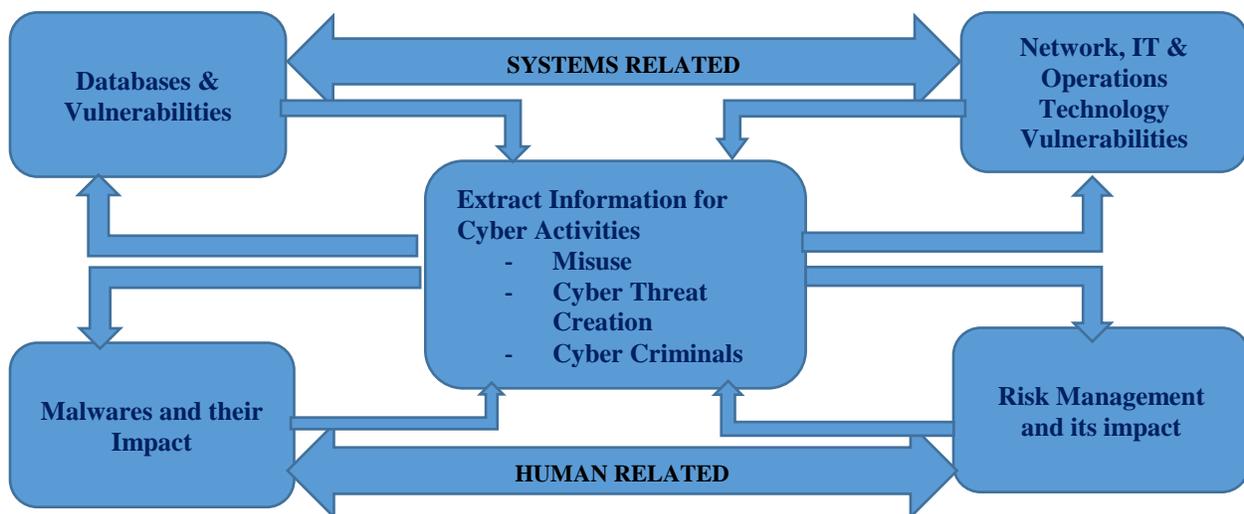
with two loops created by human and systems respectively, as shown below figure. CS education is evolved as centrally located around four prominent continuous cyclic looping areas as detailed below; with human and system related.

**A. Databases and vulnerabilities:** This goes databases and vulnerabilities; addressing mostly software and related issues. Here the issue is to store, retrieve, and adoptability of data, without falling under the trap of cyber thefts/crimes?

**B. Network, IT and operations technology vulnerabilities:** The second cycle goes through several IT/CS infrastructures and application software. Here the main issues are going through password cracking, message trapping and re-installation of data/information on track, along with existing software vulnerabilities.

**C. Malware and their impact:** This is a state-sponsored malicious code (virus), originally designed for offline, but quickly gained its momentum with the help of networking and Internet; throwing big challenges to CS team.

**D. Risk management and its impact:** This is another human-made process of assessing the probabilities and consequences of risk events if they are realized; guides CS and EDM personnel.



The traditional approach to CS have been to use a prevention-centric strategy focused on blocking attacks [19]. The nonlinearity/random nature of these cyber-

crimes/threats, makes corporate vision more dynamic. Advanced/motivated threat actors are circumventing perimeter are based defenses with creative, stealthy, targeted and

persistent attacks; often go undetected for some time period.

### **CRITICAL THINKING LIFE CYCLE Vs PHASES OF CYBER SECURITY**

Once we are ready to teach CT skills, one should be ready to use some visual aids to guide them. The below described CT life cycle is a closed loop activity, with six open-

ended questions, which are cyclic activities in a thinking process, from “what do I know?” to “how did I do”? These six activities of CT forms a continuous loop, goes again and again. These are well structured and detailed in the past literature on CT [12] [13]. These are also the six phases of CS strategic stages shown above. On the positive note this CT life cycle has many familiarities with that of CS phase

**Phase 1: Reconnaissance (What do I know?):** This primarily identify potential targets that satisfy the mission of the attackers such as financial gain, targeted access to sensitive information, or brand damage. Once they determine what defenses are in place, they choose their weapon, whether it’s a zero-day exploit, a spear-phishing campaign, bribing an employee, or some other.



**Phase 2: Initial compromise (How do I know?):** The phase is based on one premise: The initial compromise is usually in the form of hackers bypassing perimeter defenses and gaining access to the internal network through a compromised system or user account.



**Phase 3: Command & control (What is important?):** The compromised device is then used as a beachhead into an organization. Typically, this involves the attacker downloading and installing a remote-access Trojan (RAT) so they can establish persistent, long-term, remote access to your environment.



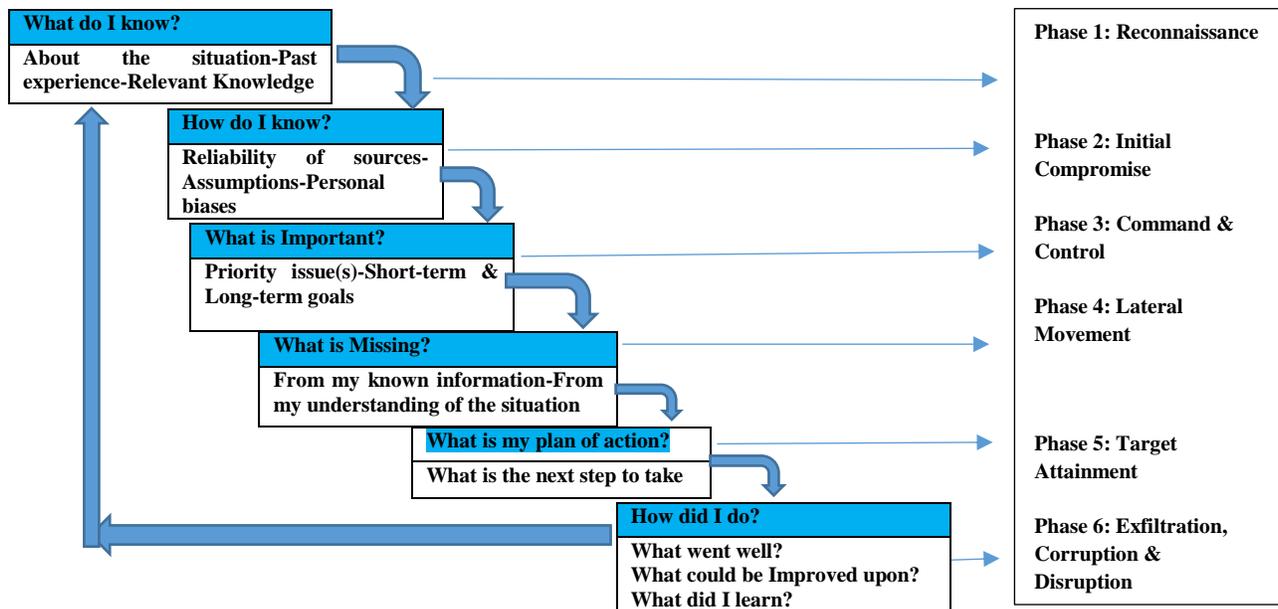
**Phase 4: Lateral movement (What is missing?):** Once the attacker has an established connection to the internal network, they seek to compromise additional systems and user accounts. Because the attacker is often impersonating an authorized user, evidence of their existence can be hard to see



**Phase 5: Target attainment (What is my Plan of Action?):** At this stage, the attacker typically has multiple remote access entry points and may have compromised hundreds (or even thousands) of internal systems and user accounts. They deeply understand the aspects of the IT environment and are within reach of their target(s).



**Phase 6: Exfiltration, corruption, and disruption (How did I do?):** The final stage is where cost to businesses rise exponentially if the attack is not defeated. This is when the attacker executes the final aspects of their mission, stealing intellectual property or other sensitive data, corrupting mission-critical systems, and generally disrupting the operations of your business.



The above detailed CT life cycle guide management professionals in several open ended questions, which help in best practices of CT in modern corporate world as described below.

### **BEST PRACTICES FOR IMPROVING THE STRONG CYBER SECURITY SKILLS**

Corporate information security must consider anything that would put the company's information at risk/danger. For creating strong CS procedures/policies, will surely off of preconceived notions about what organization needs; rather subject to a through business case analysis and security-focused risk analysis. Rapidly growing cyber threats and crimes, demands CS personnel to work in an unpredictably difficult, complex and high risk situations. In a working corporate network sudden hacking or sudden witness of a database vulnerability by an internal employer, force CS personnel to have a positive thinking mindset and strong

CT skill set [8]. CT is like new firewall for most of the cyber personnel, vigilant CS

experts have CT skills and mindset that enable them to anticipate and defend against internal and external threats [11]. The following are few suggested best practices for improving strong CS skills.

- Boss knows the best: A wrong myth
- CS is to be at corporate IT infrastructure level and should be automated
- CS awareness/education training is mandatory at all levels across the organization
- Modern businesses needs to engage CS consultants
- Create a transparent CS incident or reporting structure.
- The corporate hiring strategy should include CS awareness campaign
- Expired certificates should be deleted as soon as possible
- Restrict the browsers to force https
- Frequent running of scans over networks and databases
- High moral leadership skills coupled with interdisciplinary teams

## CONCLUSIONS

This research strongly concludes that CT is an essential task force for improving the CS across the business organizations. Since CS is mix of social science, economics and management, it is concluded that CS education is most important for modern corporate world; for better productivity and quality of services and products. The

established professional look towards CS, derives the truth that both systems as well as people intertwined nature and responsible for CS. This research also establish a mapping between CT life cycle and the different phases of CS, for an easy conclusion that CS education needs to be evolve cyclically; with new security breaches every day.

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