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THE NEED FOR AND THE TRAINING OF COMPLEX PROBLEM-SOLVING SKILLS

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Abstract:
There is an increasing global need for generic skills for the 21st Century and problem solving has been shown to be one of the most needed of these skills. However, it is not clear as to what is being done by education and training institutions to develop problem solving skills, especially relating to solving complex problems. The general purpose of this research was to investigate the extent of the need for problem solving skills and the extent to which problem-solving training courses focus on complex problem solving (CPS). Literature reviews were conducted of; a) studies that investigated the need for generic skills, including problem solving skills, b) problem solving training courses advertised on the Internet, and c) the CPS literature. The findings confirm that there is a substantial global need for problem solving skills, but the problem-solving courses advertised by universities and training institutions vary considerably in their content and do not adequately address CPS. Based on these findings and the literature review, a holistic and integrated model of CPS is proposed with the aim of contributing to the conceptualisation of CPS, the training of CPS and its practical implementation. The main practical implication of these findings is that universities and training institutions should seriously consider offering CPS training courses based on a holistic and integrated model. Also, senior managers should incorporate the training of CPS skills into their Human Resource strategic thinking and planning.

Keywords: problem solving, generic skills, core skills, key competencies

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1. Introduction

1.1 Background

As a result of the 4th Industrial Revolution many occupations and jobs are becoming redundant and many are being created with the result that new skills have to be learned urgently. During 2016 and 2018 the World Economic Forum (WEF) reported on two extensive surveys they had conducted amongst large businesses in many countries to investigate the skills that will be needed up to and including 2022. The findings of these two studies show that there is a substantial need for generic skills in a wide variety of occupations and jobs and complex problem solving (CPS) stands out as one of the most needed of these generic skills.

However, it is not clear whether the findings of the WEF surveys can be generalized to other organisations. Also, it is not clear whether universities and training institutions are focusing on teaching CPS to meet this need.

The purpose of this study is to contribute to the understanding of CPS and to facilitate the training of CPS skills. More specifically, the aim is to answer the following research questions;

- To what extent do other studies confirm the findings of the two WEF surveys?
- To what extent are the problem-solving training courses run by universities and training institutions meeting these needs?
- What is meant by complex problem solving – is there a well-established CPS theory and framework or model?

2. Research methods

The research methods consisted of reviews of a) additional surveys carried out by various organizations on the need for generic skills, b) advertisements on the Internet for problem solving training courses, and c) the literature on CPS and related mental processes.

The search for other major surveys/studies relating to the need for generic skills was conducted on the Internet and the related reports were downloaded. The relevant data were then recorded in a Word table, which is shown as Table 2 of this article.

The Internet search for advertisements for problem solving training courses was based on a convenience sample of university and private training courses and involved entering keywords into the Google search engine and identifying websites that clearly indicated the content of their courses. The URLs were saved and the data on the content and duration of the courses were recorded on Excel spreadsheets. A summary of the results is shown in Table 3.

2.1 Ethical considerations

This study has ensured the anonymity and confidentiality of the information obtained via the Internet even though the information is publicly available. Also, considerable attention has been given to providing information in this article that is accurate and unbiased.

2.2 Reliability

As mentioned, much attention has been given to providing information that was accurate at the time it was accessed (June/July, 2019). However, it must be kept in mind that the information reported here could change with time.

2.3 Validity

A number of the reviewed generic skills studies predict the need for these skills some years into the future. The predictive validity of the information provided by these survey reports is therefore dependent on the fairly subjective assessments of the officials who completed the survey questionnaires. The WEF appears to have undertaken to repeat its survey once every two years so the predictive validity of the information they provided could be assessed over time.

In relation to content validity, there could be inaccuracies relating to the respondents' interpretations of concepts mentioned in the survey questionnaires. For example, it is not clear whether the respondents understood the concept of complex problem solving as opposed to simple problem solving. Nevertheless, given the seniority of the respondents it is reasonable to assume that they had a fairly accurate understanding of the concepts and terminology involved in the survey questionnaires.

Another issue with validity is the extent to which the elements in the proposed model, such as the modes of thinking, are relevant to CPS. At this stage it does appear that they are highly relevant and valid, but this would have to be established by further research.

3. Literature review

The literature review consists of reviews of;

- studies that have been conducted since 2012 on the need for generic skills, including CPS
- theoretical publications relating to CPS and
- publications relating to the modes of thinking and other mental processes included in the proposed model of CPS.

3.1 The need for generic skills: major studies carried out since 2012

This section briefly outlines eight studies and lists the generic skills they have found to be important. (Note that generic skills are also referred to as core skills and key competencies.)

A. National Research Council (2012) ***Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century***

In 2012 a NRC committee consisting of members from the US National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine produced their report based mainly on extensive literature studies.

The first part of the NRC report lists the following main "*cognitive processes and strategies*" that the committee considered important; critical thinking, problem solving, analysis, reasoning/argumentation, interpretation, decision making, adaptive learning, and executive function.

The second part of the report lists the following O*NET skills identified as important by the committee; system skills, process skills and complex problem-solving skills. (O*NET is an open online database of over 900 occupations, related skills and characteristics and is run by the US Department of Labor**.)**

B. World Economic Forum (2016) ***The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution***

Responses were obtained from 371 companies in 15 "*major developed and emerging economies and regional economic areas*." Table 1 of this article summarises the findings of the WEF survey in relation to the core skills that respondents anticipated would experience an increase in demand by 2020.

Table 1: WEF Report (2016): Increase in Skills Demand to 2020

Core Skills	**Percentage of jobs that will experience an increase in demand**
Cognitive Abilities	15 %
Systems Skills	17%
Complex Problem Solving	36%
Content Skills	10%
Process Skills	18%
Social Skills	19%
Resource Management Skills	13%
Technical Skills	12%
Physical Abilities	4%

Source: Figure 10 of the WEF report (2016).

In relation to the results shown in Table 1, the WEF report specifically points out that 36% of all jobs in the responding organisations will require complex problem solving as one of their core skills.

C. World Economic Forum (2018) ***Future of jobs report***

The WEF conducted a follow-up survey amongst 313 large global companies from a wide range of industrial sectors to investigate the skills needed by 2022. The results of the survey show that the respondents anticipate that their companies will need the following skills by 2022: analytical thinking and innovation; active learning and learning strategies; creativity, originality and initiative; technology design and programming; critical thinking and analysis; complex problem solving, leadership and social influence; emotional intelligence; reasoning, problem solving and ideation; systems analysis and evaluation.

D. Hewlett Foundation report (2016) ***21st-Century Competencies and Their Impact: An Interdisciplinary Literature Review***

The Hewlett Foundation conducted a literature review and identified the following "analytic" skills: critical thinking, problem solving, decision making, research and enquiry.

E. ***Bloomberg Job Skills Report*** **(2016)**

This report presents the results of a survey of 1,251 job recruiters in 547 US companies. According to the report, the skills that are both highly sort after and the most difficult to find (the "Sweet spot skills") are leadership, strategic thinking, communication skills, and creative problem solving.

F. Pearson Survey report (2017) ***The Future of Skills: Employment in 2030***

This study used "*foresight workshops*," in which panels of experts discussed the prospects of numerous occupations in the light of trends in the UK and the USA. They then used "*machine learning*" to predict the skills that will be needed by 2030 for all O*NET occupations.

The Pearson report consists of two parts - the skills needed in the USA and those in the UK.

The top cognitive skills identified for the USA were; learning strategies, social perceptiveness, active learning, active listening, complex problem solving, judgement and decision making, deductive reasoning, critical thinking and systems evaluation.

The top cognitive skills identified for the UK were: judgement and decision making, active learning, learning strategies, systems evaluation, deductive reasoning, complex problem solving, systems analysis and critical thinking.

G. UK Department for Education (2018) ***Employer Skills Survey Report***

This survey, which involved over 87,000 employers in the UK, focused on current skills needed and did not attempt to predict skills needed in the future. Nevertheless, the results are relevant and the report groups the skills needed into two categories; technical & practical skills and people & personal skills. The main skills lacking in the technical & practical category were operational skills, digital skills and complex analytical skills, which include CPS skills. In particular, the report states that, on average, 41% of the available labour force (applicants) and 38% of the existing labour force were lacking in CPS skills. (Perhaps coincidentally, these percentages are similar to the 36% for CPS skills reported in the 2016 WEF report.)

The main people & personal skills lacking were self-management, management & leadership, and sales & customer handling skills.

H. Brookings Institute survey report (2018) ***Education system alignment for 21st century skills***

The Brookings institute conducted a survey of the skills that were identified in national educational policy documents of 152 countries. The report states that communication,

creativity, critical thinking, and problem solving were the four most frequently identified skills.

3.2 Summary of findings of generic skills surveys

Table 2 indicates the generic skills identified by each of the studies mentioned above. There are eight studies – the Pearson and NRC studies consist of two parts. The total number of studies that identified each generic skill is listed in the column headed, *Total*. Note that all the respondents identified problem solving in one form or another.

Table 2: The need for generic skills as identified by each survey

Generic Skills	Total	WEF 2016	WEF 2018	Bloomberg	Pearson (USA)	Pearson (UK)	UK Employers	Brookings	NRC	NRC O*NET	Hewlett
Complex problem solving	6	√	√		√	√	√			√	
Problem solving	3							√	√		√
Creative problem solving	1			√							
Learning	6	√	√		√	√		√	√		
Critical thinking	6	√	√		√			√	√		√
Analytical thinking	5	√	√				√		√	√	
Systems thinking	4	√	√		√					√	
Leadership	3	√	√	√							
Reasoning	3		√		√				√		
Decision making	3				√				√		√
Social skills/ teamwork	2		√		√						
Creativity / innovation	2	√	√								
Process/operational skills	2						√			√	
Emotional intelligence	2	√	√								
Self-management	1						√				
Initiative & enterprise	1	√									
Active listening	1				√						
Strategic thinking	1			√							
Interpretation	1								√		
Research & enquiry	1										√
Sales, customer handling							√				

3.3 Survey of training courses in problem solving

An Internet search was conducted by this author for advertisements placed by universities and training institutions for their problem-solving courses. The search found usable advertisements placed by a total of 50 universities in Australia, Singapore, South Africa, Britain, Canada, Holland and the USA, and 57 usable advertisements placed by private training institutions in Australia, Singapore, South Africa, Britain and the USA. Table 3 shows the main aspects of problem solving covered by the courses as well as the number of universities and training institutions that focused on these aspects.

3.4 Summary of findings of the review of problem-solving courses

Most of the "problem solving" courses reviewed focused on only one or two aspects or dimensions of problem solving. However, the advertisement of one course mentions CPS and the course includes 5 aspects of CPS. Table 3 shows that, in total, the five most common courses offered were on creativity/innovation, analytical thinking, steps in the problem-solving process, critical thinking and team problem solving. The variation in the aspects dealt with by the courses indicates that, although each aspect is clearly closely related to problem solving, there is a substantial variation in the conceptualisation of problem solving amongst the people who designed the courses.

Table 3: Problem solving courses offered by universities and training institutions

Main aspects of problem-solving covered	**Total out of 107**	**%**	**Number of universities out of 50**	**%**	**Number of training institutions /57**	**%**
Creativity/ innovation	69	64	30	60	39	68
Analytical thinking	63	59	27	54	36	63
Steps in the problem-solving process	50	47	17	34	33	58
Critical thinking	34	32	23	46	11	19
Team problem solving	24	22	13	26	11	19
Collaboration	8	7	5	10	3	5
Systems thinking	6	6	6	12	0	0
Ethics	3	3	3	6	0	0
Intuition	3	3	3	6	0	0
Cognitive psychology	1	1	1	2	0	0

3.5 Brief review of literature relating to CPS

In their historical review of CPS Fischer, Funke and Greiff (2017) explain that research on CPS started in the 1970s with the publication of papers by Dorner (1975), Dorner, Drewes & Reither (1975) and Meadows (1972). These articles stressed the need to move from studying problem solving in laboratory situations to more realistic situations mainly because of the complexity of global problems during the 1970s, such as the oil crisis of 1973. Subsequently, researchers used computer simulations of fictional complex problems as a basis for studying the complex problem-solving process. The Putz-Osterloh "Tailorshop" is an example of such a simulation and is explained by Fischer, Grieff & Funke (2012.)

Fischer et al (2017) also point out that Dorner (1975) proposed that simulations of complex problems could be used as a basis for assessing CPS skills. However, this proved to be difficult because of the heterogeneous nature of complex problems so to try to overcome this difficulty Funke (1995) proposed a framework of CPS that has three main variables; the problem solver, the task and the environment. According to his framework, "*CPS is viewed as the interaction between a problem solver and a task in the context of an environment*." The main variables relating to the problem solver are memory, information processing and non-cognitive variables such as motivation, self-confidence and perseverance. The task is essentially the process of achieving specified goals by

overcoming barriers between the given state and the goal. The environment includes additional information, resources, disturbances, feedback, and pressures.

Of special note is the definition of CPS formulated by Frensch and Funke (2005), which reads as follows;

> "*CPS occurs to overcome barriers between a given state and a desired goal state by means of behavioural and/or cognitive, multi-step activities. The given state, goal state, and barriers between given state and goal state are complex, change dynamically during problem solving, and are intransparent. The exact properties of the given state, goal state, and barriers are unknown to the solver at the outset. CPS implies a very efficient interaction between a solver and the situation requirements of the task, and involves a solver's cognitive, emotional, personal, and social abilities and knowledge*."
>
>

Fischer, Greiff, and Funke (2012) explain that the multi-step aspect of CPS consists of four phases;

1) Information retrieval and information integration
2) Goal elaboration and goal balancing
3) Action planning and decision-making, and
4) Self-management

Fischer et al (2012) then go on to elaborate on the CPS process by explaining that, given the current state and the goal state, there is a search for possible solutions using selected methods. However, the application of these methods as well as changes in the environment and the possible consequences of the actual application of solutions may lead to new problems or even new possible solutions. They point out that if a method is not successful in achieving the goal it can be aborted and a new method can be tried. Alternatively, the problem may be reformulated or the whole attempt to solve the problem may be aborted. We can deduce from this that the steps in the complex problem-solving process are not fixed but are iterative and CPS is often a trial and error process. Furthermore, they explain that in order to gain information and knowledge about a problem, problem solvers explore the system's behaviour using a known strategy and this leads to an understanding of the state of the system. The problem solver then refines his or her knowledge about the system by eliminating irrelevant information and develops an "*internal representation*" of the system. (Note that this is similar to Senge's (1990) mental model.) On the basis of this knowledge and understanding of the system, the problem solver is able to implement a solution and monitor the implementation by obtaining feedback from the environment. If the feedback is negative, he or she can change the solution and/or the goals. Fischer et al state that their explanation of this process is based on "*the theoretical and empirical contributions of the interdisciplinary field presented in the previous sections*," and point out that a holistic approach to CPS should be taken because of the interaction of the parts of the problem.

On the question of what makes a problem complex, Funke, J. (2012) lists five features of complex problems that differentiate them from simple problems; the complexity of the problem situation; the connectivity between the variables involved, the dynamics of the situation – it changes over time, the "*intransparancy*" of the variables – not all the information about them is available to start with, and "politely" - they often have more than one goal and the goals are often in conflict with each other.

3.6 Summary of the main principles of CPS as revealed by the literature research

- A complex problem exists in the context of an environment.
- A complex problem can be defined as the gap between the current state and the desired or goal state.
- There are a number of goals that could be in conflict with each other.
- The goal state is achieved by means of multi-step activities.
- The CPS process involves systems thinking.
- The CPS process and the skills, abilities and knowledge involved should be viewed and studied holistically.
- The CPS process is influenced by the solver's cognitive, emotional, personal, and social abilities and knowledge.

3.7 Literature relating to the elements in the proposed model

The generic skills studies outlined above list a number of modes of thinking such as critical thinking, creative thinking and systems thinking. A literature review was carried out by this author on these modes of thinking as well as emotions, feelings, intuition and insight and the roles they play in problem solving. The relevant publications are discussed briefly in the sections below.

4. Proposed model for complex problem solving

The generic skills studies and the survey of training courses discussed above show that there is a lack of a common understanding of what problem solving consists of and there is an almost total lack of attention paid to CPS in the problem solving courses that were reviewed. Also, considering that CPS usually requires a collaborative and joint problem-solving approach, it is clear that there is a need for a commonly understood conceptual model such as the one proposed in Figure 1.

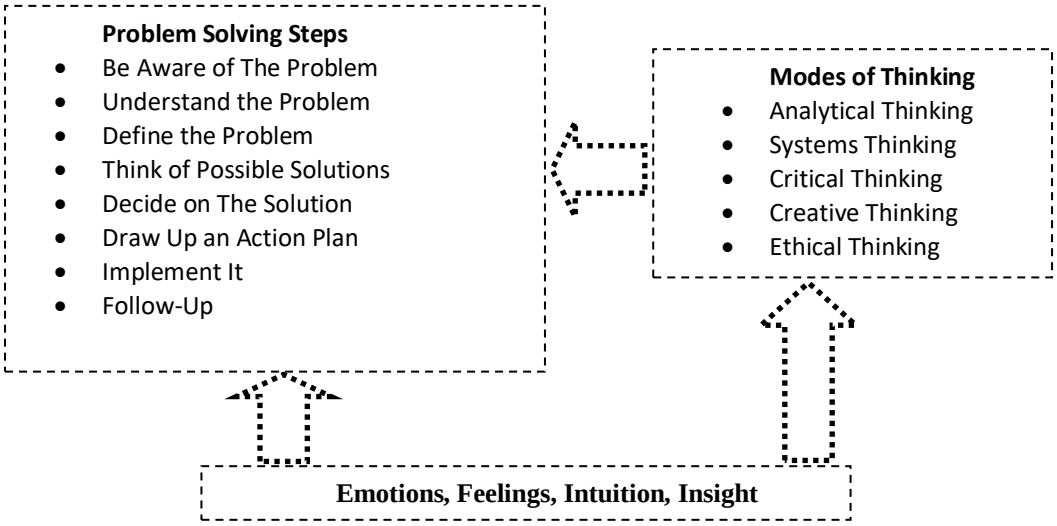

Figure 1: The proposed CPS model

The selection of the elements in the proposed model was informed by the generic skills listed in Tables 2 and 3, the literature review on CPS (especially the definition of CPS proposed by Frensch and Funke, 2005) and the potential of each element to contribute to the training and practical application of CPS.

The problem-solving steps form the core of the model and the other elements feed into the process where appropriate. The model does not indicate any direct causal relationships between the various elements but it is clear that many overlaps exist between them and they can be integrated in numerous ways in the CPS process depending on the nature of the problem and the step or stage in the process.

The following sections briefly define and/or explain each of the elements of the proposed CPS model.

4.1 Analytical thinking

Wilson (2016) explains that analysing is, "*breaking materials or concepts into parts, determining how the parts relate to one another or how they interrelate, or how the parts relate to an overall structure or purpose*." Analytical thinking and it's more advanced version, the scientific method, have achieved and continue to achieve amazing results with the invention and development of thousands of products and technologies but they have sometimes resulted in unfortunate consequences. For example, the invention of fractional distillation of raw petroleum led to the petroleum industry but the combustion of petroleum has contributed to pollution and global warming. Also, the splitting of the atom led to the atomic bomb. One reason for these undesirable consequences is a lack of understanding of the complexities of the systems and environments in which the inventions and new technologies existed.

4.2 Systems thinking

Systems thinking considers the problem in the context of the system and the environment in which it is embedded and investigates how the parts of the system (the sub-systems) dynamically interact in a holistic way with each other and their environment. Peter Senge

(1990) explains that, "*The essence of the discipline of systems thinking lies in a shift of mind; seeing interrelationships rather than linear cause effect chains, and seeing processes of change rather than snapshots.*" Essentially, there are two main ways of thinking about a system: as a transformation process (Figure 2) and as an open system.

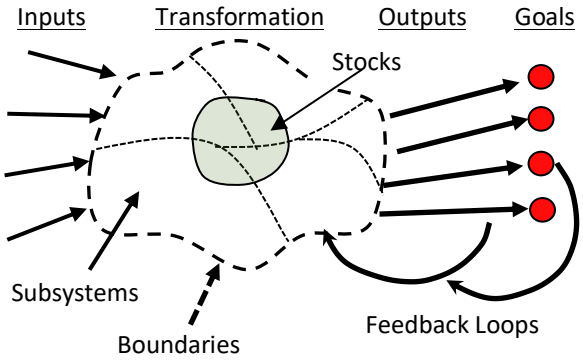

Figure 2: The transformation process view of a system

In brief, the system receives inputs from its environment and/or other systems, retains some of the inputs in stock, transforms inputs into products, places them in stock then sends them as outputs from the system to other systems and into the environment. The subsystems work together (synergistically) to achieve a common goal or a set of goals for the system as a whole. The system and subsystems have boundaries that could be physical or conceptual. The feedback consists of energy to keep the system "alive" and information that it uses to monitor its progress towards its goals. There are also many feedback loops between the various elements of the system, its subsystems and its environment.

All real-world systems constantly interact with their environment – they are open systems. So, to understand how a system works one also has to understand how it is affected by its environment and how it affects the environment. For example, a business organization can be regarded as an open system that interacts with numerous factors in its environment such as; the law, trade unions, competitors, customers, suppliers, the availability of skilled labour, and the state of the economy. (The people and organisations associated with the organization are also stakeholders in that organization and, where appropriate, should be involved in the decision making and problem-solving processes.) From a systems thinking point of view, this complex web of interactions should be viewed holistically if one is to understand the causes and consequences of problems, especially the possible consequences of proposed solutions to problems.

4.3 Critical thinking

According to the American Psychological Association Dictionary of Psychology, critical thinking is a, "*form of directed, problem-focused thinking in which the individual tests ideas or possible solutions for errors or drawbacks*."

Sternberg (1986) explains, "*Critical thinking comprises the mental processes, strategies, and representations people use to solve problems, make decisions, and learn new concepts.*"

Cottrell (2011) lists a number of specific critical thinking skills, such as; identifying other people's positions, arguments and conclusions; evaluating the evidence for alternative points of view; and weighing up opposing arguments and evidence fairly.

Critical thinking applies throughout the problem-solving process but is especially applicable when considering the information that has been gathered about the nature of the problem, its causes and consequences.

4.4 Creative thinking

The American Psychological Association Dictionary of Psychology defines creative thinking as "*the mental processes leading to a new invention, solution, or synthesis in any area. A creative solution may use preexisting elements (e.g., objects, ideas) but creates a new relationship between them. Products of creative thinking include, for example, new machines, social ideas, scientific theories, and artistic works*".

In the CPS process creative thinking applies especially to the generation of ideas to solve problems, the implementation of these ideas and attempts to overcome barriers to achieving goals.

4.5 Ethical thinking

The Longman Dictionary of Contemporary English defines ethics as, "*moral rules or principles of behaviour for deciding what is right or wrong*." As such, ethics applies mainly to the decision-making step in the problem-solving process. These fairly subjective rules, standards, principles or ideals relate to moral aspects such as trust, justice, equity, honesty, reliability, cooperation, corruption, safety, sexual harassment and respect for others in general. They indicate how we ought to live and typically vary from country to country, culture to culture, and religion to religion.

The appropriate rule or principle to apply in a particular case could be subject to biases, prejudices, emotions and feelings. Thagard (2010) points out that ethical thinking can involve both emotions and rational thinking which should be "meshed" in order to "*act well and correct injustices*." He comments that, "*Being good requires both thinking and feeling*."

Whysall (1998) focuses on business ethics in decision-making and points out that many companies have codes of ethics that guide their practices. He provides a number of practical examples of how ethics should be taken into consideration when managers make decisions.

While Whysall focuses on ethics in business, Prozesky (2018) is concerned with ethics as applied in general. He explains,

> "*Globalization is making the world one country in matters of the environment, economy, trade, communications and some sporting codes like football and athletics. Each of these powerful new realities brings new and important ethical problems, from pollution to Internet invasions of privacy and match-fixing. They call for a cooperative, creative project supported by people of goodwill in all religious faiths, and none, to build a*

genuinely global ethic in the form of an agreed set of core values and an agreed account of why they should be practised."

4.6 Emotions & Feelings

These are not modes of thinking, but it has been shown that emotions are critical to decision making and problem solving.

Damasio (2010), a neuroscientist, postulates that emotions are the nonconscious and automatic physiological and neurological responses of the body to external events as well as to conscious thoughts. Examples of these automatic responses are changes in blood pressure, pulse rate and adrenaline production. According to Damasio, feelings are the conscious experience of these automatic responses in the body, i.e. of emotions. He also found that people with damage to their emotional centres of their brain found it difficult to make even simple decisions, like which restaurant to eat at.

Lerner et al (2014) quote many studies that indicate that psychological scientists now assume that emotions are the dominant driver of most meaningful decisions in life. However, excessive emotions can cloud the decision-making process so they should be managed to achieve a balance between rational thinking and emotional states. A person's ability to maintain this balance is referred to by Goleman (1996) as emotional intelligence. A comprehensive list of guidelines for controlling emotions is presented in Appendix D of Goleman's book.

4.7 Intuition

Hodgkinson et al (2008) define intuition as an "*affectively-charged judgement that arises through rapid nonconscious, and holistic associations*." Or, to put it more simply, intuition is a vague feeling that something is right or wrong, or different from the usual. This feeling appears to stem from vague, nonconscious memories of what happened in similar situations, i.e. from past experiences.

There is growing evidence that senior managers of organizations often use their intuition to make important decisions about complex, ill-defined problems. For example, Miller and Ireland (2005) quote a study by a US executive search firm which, "*found that almost half of corporate executives use intuition more than formal analysis to run their companies*." Also, Morris & Cunningham, (2013) carried out a literature review of intuition among senior leaders and concluded, "*leaders perceived intuition as a reliable cognitive tool, in some cases preferable to evidence-based, rational approaches to decision making and problem solving*."

However, Khaneman (2011), Thagard (2001) and Myers (2002) caution against impulsive decision making on the basis of intuitions alone. Khaneman (2011) explains numerous "*flaws*" in intuitive decision making such as flawed perceptions, the anchor effect, the illusion of understanding, framing, loss aversion and the planning fallacy. He states that the way to overcome these flaws is to back up your intuition with rational, logical thinking. Thagard (2001) refers to this approach as "*informed intuition*."

In relation to the proposed model, the rational elements are analytical thinking, systems thinking, critical thinking, creative thinking and, to a large extent, ethical thinking.

4.8 Insight

Longman's dictionary of contemporary English defines insight as, "*a sudden clear understanding of something or part of something, especially a complicated situation or idea*." Hodgkinson et al (2008) quote a number of studies that show that insight often occurs after a period of "*incubation*" which occurs after an "*impasse*" in the problem-solving process. Achieving insight obviously has benefits in relation to understanding a problem situation, identifying its causes and consequences and generating solutions.

4.9 The steps in the CPS process

Table 3 above shows that 50 of the 107 problem solving courses reviewed were based on steps in the problem-solving process. The concept of a series of problem-solving steps is also fairly common in the literature. For example, Huitt (1992) states that most models of problem-solving, and decision making include at least four phases; an input phase, a processing phase, an output phase and a review phase. Also, Jennings and Wattam, (1998) explain seven "*activities*" in their "*normative decision-making process*," Checkland (1999) outlines seven "*stages*" in the soft systems approach to problem solving, Twigg and Black (2016) propose seven "*steps*," and the US Federal Emergency Management Agency (FEMA) uses a five-step problem solving model that it maintains has proved to be successful. Also, Frensch and Funke's definition of CPS states that it is a multi-step process.

In the proposed model in this article the problem-solving process consists of 8 steps. The wording of these steps is designed to facilitate the integration of the various elements in the model with the steps. The first 5 steps can be considered as the decision-making phase and the last three steps as the implementation phase. The following are brief explanations of each step. This is an iterative process and the order of the steps is not fixed.

A. Be aware of the problem

Awareness of a problem could be triggered by intuition, information, messages or signals (usually visual or audio) that indicate that either the situation is not as it should be or that there is an opportunity to improve it.

B. Understand the problem

The causes, consequences, and seriousness of the problem need to be understood in the context of the system and the environment in which it exists. This is where systems thinking is helpful. Also, in order to understand a problem fully one needs information and this information should be accurate, comprehensive and up-to-date. The focus of this step should be on a critical analysis of the information rather than relying on hearsay,

opinions, feelings, and questionable assumptions and beliefs. In particular, it is important to look for trends, which is an important aspect of systems thinking.

C. Define the problem

A problem is defined as the gap between an existing state and a desired goal state. In some cases, these states might be relatively easy to determine (e.g. actual costs versus budgeted costs) but in others considerable thought has to be given to clarifying each state so that the gap can be determined. This is particularly important where a number of people are involved in trying to solve the problem. The greater the agreement on the definition, the greater the chance of resolving the problem.

According to the research carried out by Locke and Latham (1990), specifically stated goals are more effective than vague goals, which means that they should be measurable and have a target date. However, in highly complex problem situations it is not always possible to state specific goals and in these cases scenario planning might be more relevant. From a systems thinking point of view the goal or goals of the system in which the problem exists could coincide with the goal/s identified for solving the problem. A typical characteristic of CPS is that there are often multiple goals involved, some of which could be sub-goals or interim goals, and these goals can be in conflict with each other.

D. Think of alternative solutions

This step is based on the principle that one should not jump to a conclusion about a solution to a problem but should spend time thinking of a number of possible solutions to improve the probability of arriving at an effective solution. This involves creative or lateral thinking, which, according to De Bono (1990) is to "*look at things in different ways, to restructure patterns, to generate alternatives.*"

E. Decide on the solution to be implemented

When deciding which possible solution is the best or most suitable under the circumstances each of the alternative solutions should be considered, preferably according to a set of criteria such as the likelihood that it will achieve the goal, time implications, costs, availability of funds, whether people with the required skills are available, the likely effect on the system, the environment and people involved as well as the ethical and legal implications. In particular, the possible consequences of the envisaged solutions should be considered in detail.

F. Draw up an action plan

A good decision could be made ineffective if the implementation of the decision is not planned carefully. A plan consists of three main aspects, a starting point (where you are now), an end point (where you want to be) and a series of action steps to get you from the start to the end. This is the same concept as defining a problem as the gap between the actual state and the desired state. The plan should specify the various activities that need to be taken, by when and who is responsible for those activities.

G. Implement the plan

This step is critical to actually solving the problem. The traditional management functions of planning, leading, organizing and controlling apply as do the need for appropriate technical skills, knowhow, and the commitment and motivation of all the people involved.

H. Follow-up

Follow-up involves monitoring and evaluating the implementation process to ensure that the goals are (or will be) achieved, ensuring that additional problems are not being caused and taking corrective action if necessary. Follow-up should take place regularly while the work is being done, at the end when the solution has been implemented, and sometime after the completion of the implementation phase. In some cases, the solution being implemented might prove to be such a failure that it has to be abandoned and the problem-solving process repeated. This trial and error approach is common when trying to solve complex problems – it is a learning process.

5. Results and discussion

The following discussion follows the order of the research questions explained in the introduction of this article.

In relation to the extent of the need for problem solving skills, all eight of the generic skills studies reviewed confirm the need for problem solving skills, and the need for complex problem-solving skills is mentioned by five of the studies.

In answer to the research question relating to what is being done to develop problem solving skills, the analysis carried out on the content of the advertisements for the 107 problem solving courses shows that most of the courses focused on only one or two aspects of problem solving and the aspects covered by the courses varied substantially from course to course, which indicates a big variation in the conceptualization of problem solving. It appears that designers of these "*problem solving*" training courses view the mental processes they focus on as being equivalent to the problem-solving process. Differences in the conceptualisation of problem solving are also evident in the results of the generic skills studies as shown in Table 2. The studies list problem solving and complex problem solving separately from other generic skills such as systems thinking, critical thinking and creative thinking. There is clearly a need to clarify the meaning of CPS and how the other mental processes relate to it. Hence the review of the CPS literature.

In particular, the general framework of CPS proposed by Funke (1995) and the definition put forward by Frensch and Funke (2005) go a long way to clarifying the meaning of the CPS process. However, as pointed out by Funke (2012), there is no broadly accepted CPS theory. Hopefully, the model of CPS proposed in this article will make a contribution towards such a theory.

5.1 Practical implications

The practical implications of the results of this study are that although there is a well-established need for problem solving skills, especially complex problem-solving skills, very little is being done to develop these skills in any meaningful way. Consequently, there is a risk that many people will not be able to cope with the job demands of the 4th Industrial Revolution and, as a result, there is also a high risk that organisations will not be able to meet their short, medium and long term operational and strategic goals.

5.2 Limitations

- A limitation of this study is that it focused on Anglophone publications and websites.
- Some variables mentioned in the reviewed studies and literature, such as learning, motivation, collaboration and group/team problem solving, are not included in the proposed model as this author considers them to be ancillary factors but the model could be extended to include them.
- The model does not indicate causal relationships as they have not been established reliably. This could limit the type of research based on the model but it also indicates a particular need for further research.
- The model is limited to the elements in the problem solving process and does not address specific techniques such as brainstorming, the nominal group technique, force field analyses, cost/benefit analyses, SWOT analyses, feedback loops, mind maps and simulations, all of which are tools to be used where appropriate in the problem solving process.

5.3 Recommendations

It is recommended that;

- Similar studies should be carried out in other languages and countries.
- A more holistic and integrated approach to complex problem solving should be taken and the proposed model could be used as a starting point.
- Relevant bodies and experts should develop educational and training programmes that take into consideration this more holistic and integrated approach.
- Universities and training institutions should seriously consider integrating CPS into their curricula and this would mean more emphasis on the elements of the proposed model.
- Sufficient time should be allocated to each aspect of training and education courses and programmes.
- Research into complex problem solving should be encouraged, especially action research into the efficacy of the elements of the proposed model and the most effective pedagogical methods.
- Greater emphasis should be placed on the training of teachers and trainers/facilitators in the various concepts, approaches and pedagogical techniques relating to CPS.

- CPS should be an important aspect of Strategic Human Resource Management.

6. Conclusion

The skill in solving complex problems effectively is critical for individuals, teams, and organizations, including governments, and should be developed through education and training by applying a more holistic and integrated approach to the discipline of CPS.

Conflict of interests
The author declares no conflict of interest.

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