A COMPETENCE FRAMEWORK FOR INNOVATION AND SUSTAINABILITY

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Abstract: Which competences enable problem solvers to successfully drive innovation and sustainable development of society? In this paper, I develop a theoretical framework consisting of (1) personal; (2) professional domain; (3) systemic; (4) creativity; and (5) sociocultural (collaborative) competences to meet complex challenges faced by today's society. I define the problem solver's competences as a person's abilities, knowledge, and skills required to adequately deal with complex real-world problems and which are affected both by their mental models and by the distinct features of their environment. This paper is aimed at providing guidance for future research in the field of competence development.

Keywords*:* Competence, competency, complex real-world problems, mental models, environmental dimensions, abilities, knowledge, skills, competence frameworks, personal competence, professional domain competence, systemic competence, creativity competence, sociocultural (collaborative) competence, education, crises, innovation.

PRISTOJNOSTI ZA INOVACIJE IN TRAJNOSTNI RAZVOJ

Povzetek: Katere sposobnost omogočajo reševalcem problemov, da se uspešno ukvarjajo z inovacijami in trajnostnim razvojem družbe? V tem prispevku razvijam teoretičen model, katerega sestavljajo sposobnosti: (1) osebne, (2) poklicne, (3) sistemske, (4) ustvarjalne in (5) za kulturo druženja (sodelovanja); vse so pogoj, da se človek spopade z zapletenimi izzivi današnje družbe. Problem sposobnosti reševalca problemov definiram kot sposobnosti, znanje in spretnosti tega človeka, ki jih potrebuje, da se ustrezno ukvarja z zapletenimi problemi dejanskega sveta; na njih vplivajo človekovi mentalni modeli in posebne lastnosti okolja. Prispevek naj bi dal napotke za bodoče raziskovanje o razvoju sposobnosti.

Ključne besede: strokovnost, pristojnost, zapleteni problemi dejanskega sveta, miselni modeli, okolje dimenzije, zmožnosti, znanje, spretnosti, okvir sposobnosti, osebna sposobnost, sposobnost na strokovnem področju, sistemska sposobnost, sposobnost ustvarjati, sposobnost za kulturo druženja (sodelovanja), usposabljanje, krize, inovacija

INTRODUCTION

Competences are considered important determinants of individual and collaborative performance (e.g., McClelland, 1998; Boyatzis, 1982, 2001, 2007; Erpenbeck & von Rosenstiel, 2007; Raven & Stephenson, 2001); however, a coherent *competence theory* ascertaining competences that are needed for solving complex real-world problems is currently missing. Further shortcomings of previous research in this field stem from: a confusion regarding the difference between the terms competence and competency (e.g., McClelland, 1973 versus McClelland, 1998; Snyder & Ebeling, 1992); different meanings of competence in management strategy and human resource development literature (e.g., Delamare-Le Deist & Winterton, 2005, focus on the different use of competency versus competence especially in management strategy and human resource development literature); and a lack of a commonly agreed upon theoretical concept with respect to constituents of competence such as abilities, knowledge, and skills (e.g., Westera, 2001; Erpenbeck & Rosenstiel, 2007). Finally, while many existing frameworks tend to focus on specific fields (e.g., Man, Lau, & Chan, 2002; Inyang & Enuoh, 2009 on entrepreneurial competences or Wiek, Withycombe, & Redman, 2011 on competences in sustainability), little has been said about key competences needed for solving more general, complex real-world problems and the potential collaborative challenges associated with it (see overview given in Table 1).

At the society and policy level, a core research question of this paper is to investigate which competences are essential for individuals and collaborative entities to meet the complex challenges faced by society today. Popper and Soros have already posed the question "What competences are needed to develop a reflective and open society (Popper, 1971a, 1971b; Soros, 2000)?" By extension, one also ought to ask what competences the problem solver/s need/s in order to become driver/s for innovation and sustainable development of society. Such competences should enable individuals and collaborators to devise immediate, mid-term, and long-term solutions in both a consistent, creative, and rational manner, making them prerequisites for successful, sustainable outcomes.

As a basis for the conceptual proposition of a general framework for problem solving competencies, this paper examines existing competence frameworks and their shortcomings with respect to their applicability to complex real-world problems. The herewith newly developed framework then aims to outline competences needed to collaboratively deal with complex problems. This is achieved by highlighting five core dimensions of competences: *personal competence, professional domain competence, systemic competence, creativity competence, and sociocultural (collaborative) competence*.

A NEED FOR SYSTEMS THINKING, CREATIVITY, AND COLLABORATION

Crises have become routine in the 21st century: the current global economic crisis, food crises, global warming, genocides, energy shortages, and carcinogens are only the tip of the iceberg. Because of globalization and our constantly increasing *interconnectedness* we are affected by both near and remote crises (geographically and contextually) (e.g., World Bank, 2012; Chinn & Frieden, 2011; Lim, 2012; Reimers, 2009). Furthermore, the inherent interdependencies within a globalized world prominently highlight the responsibilities of society, of its decision makers, and of all its stakeholders for any decisions that are, or are not made, and for their consequences. Hence, in crises that we seemingly have not called upon us such as the still resonating 2008 economic crisis, a crucial question to ask is whether we, as individuals and collectives, are equipped with the capabilities needed to be constructive, effective and successful problem solvers for the sustainable development of the world – particularly its ecological, social, and economic dimensions.

The Problem with (Defining) the Problem

The man-made problems, which society faced in the past (e.g., political, economic, technological, ecological, and social issues) were vastly different from the challenges we face today. Key differences lie in their *complexity*, their actual and potential global effects, and the difficulty of pinpointing their evolution. That these 'modern' problems are *ill-defined* makes them particularly difficult to address, (1) because our knowledge of their present state is imperfect due to peculiarities of the various interrelationships and their intensities; (2) because their future state cannot fully be determined or might be ambivalent; (3) because the trajectory connecting the present with the future state(s) cannot be fully understood, e.g., related to imperfect knowledge of potential barriers occurring within the trajectory such as technological or societal disturbances; and (4) because underlying behavioral patterns of involved individuals and collaborators change, based on alternating mental models (Scholz & Tietje, 2002; Steiner, 2011: 126-127). Thus, today's systems are characterized by an increasing amount of variables, which intensely interact with each other and with their physical, material, technological, social, and cultural environment. In addition, they also have quickly changing patterns of behavior, which need to be considered as sources of potential paths to future development (Gomez & Probst, 1999; Scholz & Tietje, 2002; Scholz, 2011; Steiner, 2011), making the forecasting of a single event practically impossible. Scholz (2011) describes as an example of such a complex path of development the interaction of human systems (e.g., industrial activities) with environmental systems (e.g., water, air, and soil) as part of the larger human-environment system; this example demonstrates how human decisions (at the organizational as well as policy levels) can lead to actions that, as part of a circular learning process, can influence further decisions and simultaneously impact environmental systems, which, as a second-order reaction, interrelate with human decisions.

Systems Thinking and Creativity

Albert Einstein, when faced with the challenge of the atomic bomb, emphasized already in 1946 the need for a new way of thinking: "[…] a new type of thinking is essential if mankind is to survive and move to higher levels. […] Past thinking and methods did not prevent world wars. Future thinking must prevent wars." (Einstein, 1946). Sixty-six years later, his words still reverberate in the face of today's multi-faceted crises, given that most influential people or 'leaders' in business, politics, and academia are now narrow specialists with linear paths of logic, oftentimes leading to constrained, one-dimensional policies and similar problem solving strategies. Hence, this paper highlights the call by complex phenomena, such as crises, for a shift in education aimed at supporting students and citizens not only in achieving disciplinary excellence but also in their endeavor to holistically (i.e. systems thinking) understand systems and related problems and to creatively reframe and solve problems (sometimes related to reinventing oneself). Future successful education policies need firstly to point out those 'new' educational challenges and secondly, to provide strategies that help students and citizens to acquire the competences needed to successfully deal with complex real-world problems. *Disciplinary excellence* is not to be replaced but extended by *holistic and creative thinking*. In exploring the roots of the phenomenon of crisis, Schwaninger and Groesser (2010) contend that all crises, large and small, are caused by errors flowing from wrong actions stemming from wrong thinking generated by agents' mediocre mental models,

otherwise known as the Conant-Ashby theorem (Conant & Ashby, 1970). Consequently, a complex issue cannot be explained by applying a mono-causal linear thinking approach nor can it be solved with capabilities that might have been successful in the past, where much simpler system characteristics were in place. Likewise, the challenges society faces today and into the future, including crises in their extreme, call for a change of traditional conceptual paradigms and, more generally, for a change in our thinking patterns as well as an effective set of *cognitive* (e.g., logical reasoning and reflecting), *affective* (e.g., feeling), and *motoric* (e.g., as basis for rapid prototyping and design thinking) *capabilities* to address complex challenges; clearly, these paradigms and capabilities must also be wrapped into appropriate educational policies and practices.

Need for Collaborative Strategies

As pointed out earlier, complex problems tend to have ill-defined properties and cannot easily be solved by routine, straight-line problem solving for which one explicit solution is available and for which a system pattern relies on a well-defined algorithm.

Today, changes of system patterns are moving at increasingly faster rates at all levels of society, affecting it's e.g., physical, material, technological, social, and cultural environment. Innovations, as one specific pattern of change for example, occur not only on a technological level, but at various cultural and socioeconomic levels as well. Especially radical innovations are usually related to changing behaviors as well; for example, the telephone or the www were related to a radical change of customers' behavior and cultural changes in addition to its implications on a technological and technical level. As complexity increases, the collaborative effort (e.g., inter- and transdisciplinary approaches), the interplay of logic and creative problem solving capabilities, and approaches to understanding and acting within the problem solving process also take on greater significance (Steiner, 2009: 5; regarding knowledge integration see, e.g., Scholz & Tietje, 2002; Scholz, 2011). Consequently, a collaborative team must include not only diverse experts, but stakeholders at various levels of the problem solving system, including decision-makers and citizens as well. Furthermore, the more innovative the solution, the greater the corresponding degree of change will be. Heightened innovativeness requires increased creativity, something that can more readily be provided by a collaborative entity. The need for collaborative strategies that integrate various disciplines, and for joint collaborative processes among various organizational and societal stakeholders is emphasized by several theoretical approaches with great practical relevance such as "open innovation" and "transdisciplinary problem solving" (Chesbrough, 2003, 2006; Scholz & Tietje, 2002; Scholz, 2011), "social innovation" (e.g., Goldsmith, 2010; Goldsmith & Eggers, 2004), "open creativity" (Steiner, 2009, 2011), "society-, user-, customer- or stakeholder-driven innovation" (e.g., von Hippel, 2002, 2005; Tuomi, 2002; Vigier, 2007), and "living labs" (European Commission, 2010). However, to date, with few exceptions (e.g., Kegan, 1994; Kegan & Lahey, 2009; Scholz, 2011), scholars have mostly overlooked the specific *capabilities* needed to address the highly demanding challenges of systems thinking and collaborative problem solving. They have also largely ignored how educational policies and related educational strategies need to be designed accordingly.

DEFINITION AND CLARIFICATION

As opposed to more stable, performance-related characteristics such as a person's intelligence (e.g., Lubinski, 2004), a person's competences can be altered more easily over time, either intentionally (e.g., by educational means) or unintentionally (e.g., as part of the interaction of a person with its environment). As Boon and van der Klink (2002: 6) note, competence can be a useful term, bridging the gap between educational and vocational requirements.

I suggest that *competence can be defined as the problem solver's abilities, knowledge, and skills needed to adequately deal with a complex real-world problem; competence depends on specific underlying mental models, which themselves are not stable but change over time; and they also depend on the specific features of the environment (i.e. physical, material, technological, social, and cultural environment)* (see Figure 1). Examples for the physical, material, and technological environment are the workplace, architecture, infrastructure, availability of resources, and techniques; the social and cultural environment encompasses e.g., leadership, relationships, happiness, value systems, diversity of nationalities and ethnicities, and economic as well as political milieus. As outlined earlier, the two concepts (competence and competency) are closely related and are both performance oriented with the following distinction: (1) *competence* (as the functional approach) delineates the abilities, knowledge, and skills (interrelated with the problem solver's mental model) which people have to possess to *successfully accomplish a certain job, project, or problem*; (2) *competency* (as the behavioral approach) characterizes the abilities, knowledge, and skills (interrelated with the problem solver's mental model) that *successful people possess.*

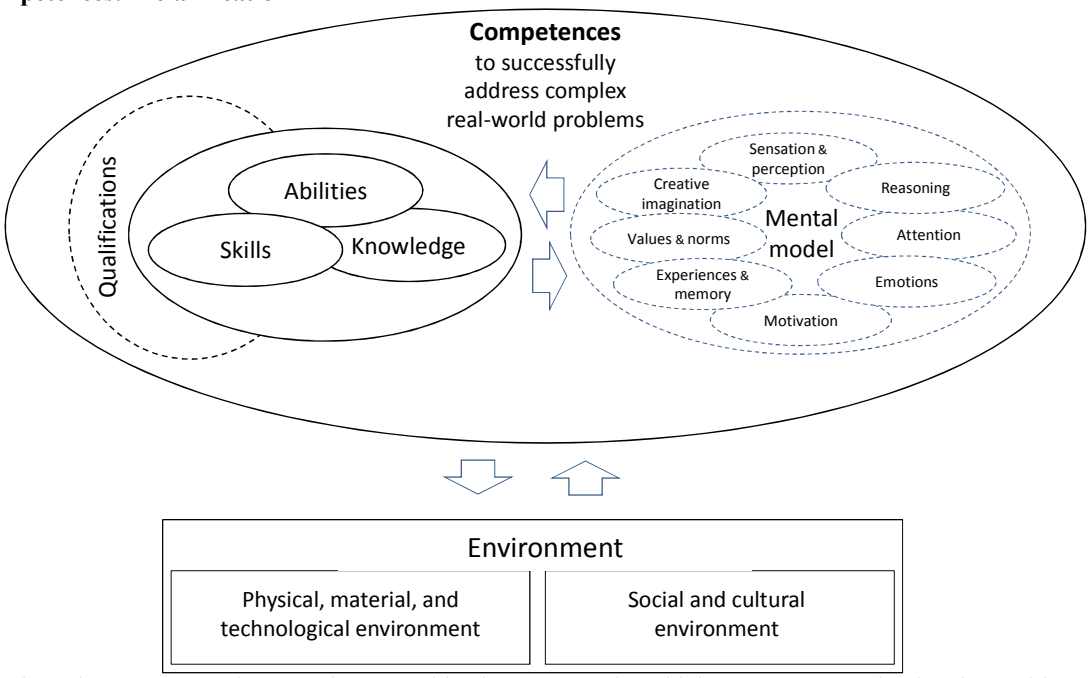
Cognitive, affective (emotional), and motoric abilities strongly correlate with the individual's talents and are more stable than skills, since abilities cannot be altered as quickly as skills; in fact, certain abilities are prerequisites for specific skills (always depending on initial conditions) (e.g., Zimbardo, Johnson, & McCann, 2009). As an example,

modeling and simulation of systems as part of the system dynamics approach is a specific skill that can be trained, based on basic intellectual abilities that allow to comprehend, analyze, and reflect the system adequately. Domain-specific and domain-general skills are the expertise gained by repeated exercises within cognitive or motoric processes.

Knowledge itself is not necessarily related to real-world action and can either be declarative respectively factual (i.e. knowledge about something), or procedural (i.e. knowledge of how to do something) and can be conveyed in explicit forms (i.e. universal knowledge that can be uttered and formally formulated in sentences) or tacit forms (i.e. "knowledge tied to the senses, tactile experiences, movement skills, intuition, unarticulated mental models" that is informal and can only marginally be communicated) (Nonaka & Krogh, 2009: 636; Nonaka, Konno, & Toyama, 2001). As Westera (2001: 75) states, declarative or factual knowledge alone no longer meets the requirements of a changing society since it is not sufficient for dealing with "ill-defined problems, contradictory information, informal collaboration, and abstract, dynamic and highly integrated processes."

Qualifications are independent of applied action and real-world experience and reflect current standardized abilities, knowledge, and skills (see also Erpenbeck & von Rosenstiel, 2007: XIX). Therefore they can only account for the formal aspects of abilities, knowledge, and skills.

FIGURE 1
Competences: A clarification



There is no commonly agreed upon, objective manner in which our senses and related cognitive and affective processes reveal an underlying (complex) problem and its enclosing, broader real-world situation to us. Similarly, there is no commonly agreed upon, objective approach to problem solving processes we are involved in, our perceived roles and competences, and interdependencies among us. Quite on the contrary, we actively construct (model) these problem solving processes by using our senses and our brain in an interplay between sensation (the stimulation of a sense organ) and perception (the mental representation of sensation) (e.g., Schacter, Gilbert, & Wegner, 2011: 125-174), reasoning (e.g., Johnson-Laird, 2010; Pinker, 2009: 299-362), attention (e.g., LaBerge, 1990), emotions (e.g., Schacter et al., 2011: 307-346; Zajonc, 1980: 151–175), motivation (Amabile, 1993; Mitchell, 1982; Robinson, Stevens, Threapleton, Vainiute, McAllister-Williams, & Gallagher, 2012), experiences and memory (e.g., Schacter et al., 2011: 219-262), values and norms (and other elements of evaluation) (Miller & Prentice, 1996; Maseland & van Hoorn, 2010; Scholz, 2011: 190-212), and creative imagination (e.g., Byrne, 1996; Steiner, 2011) (the mental model concept was originally introduced by Craik, 1943, see also e.g., Forrester, 1961, 2009; Gentner & Stevens, 1983; Porac & Thomas, 1990; Oakhill & Garnham 1996; Johnson-Laird, 1999, 2010; Sterman, 2000: 16–19). Johnson-Laird (1983, 1999, 2010) states that human reasoning depends on "envisaging the possibilities consistent with the starting point – a perception of the

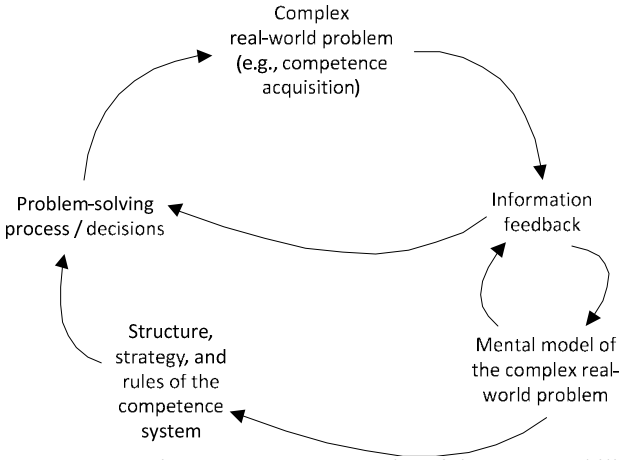
world, as set of assertions, a memory, or some mixture of them," as an alternative view for considering formal rules of inference as the underlying cognitive mechanism. By contrast, the mental model is an internal representation of the world or of its specific segments (such as a problem), for which language (either verbal or non-verbal) is needed (e.g., Chomsky, 1965; Pinker, 2007; Schacter et al., 2011: 347-388) in order to communicate or share them with others.

As shown in Figure 1, mental models not only influence the competences which are applied, but they themselves are influenced by the application of problem solver's/solvers' abilities, knowledge, and skills within a particular complex, real-world setting. In this sense, mental models are theories about the real world, which are based on individuals' unique sensations, perceptions, reasoning, attention, emotions, motivation, experiences, memory, emotions, values, norms, and creative imagination. Those theories "are not true and accurate images of our surroundings, but are only sets of assumptions and observations gained from experience" (Forrester, 2009: 13), such as being engaged within a real-world problem solving process. Mental models differ from individual to individual, although they might be members of the same problem solving team; as Forrester (2009) points out, the model may also have serious shortcomings based on incomplete information and internal contradictions.

The consideration of mental models within a theory of competences is essential. As second-order cybernetics, this effort might also be considered as thinking of thinking (e.g., von Foerster, 2003; Bateson, 2002). As pointed out by system thinkers (e.g., Forrester, 1961; Sterman, 2000; Meadows, 2008; Gharajedaghi, 2006; Scholz, 2011: 429-443), all decisions (including learning) occur in the context of feedback loops. Consequently, not only the problem solving process, but also problem solving competences for dealing with the world (and with complex, real-world problems) are influenced by their underlying mental models and vice versa. That is, the relationship between competences and mental models is not based on a linear cause-effect relationship; on the contrary, *feedback* is the core characteristic of this relationship. This feedback mechanism also forms the basis for *reframing* complex real-world problems (e.g., as an inventory of existing competences related to the needs of the specific problem such as specific actions taken to enhance competences or to acquire new ones).

Using *competence acquisition* as an example for a complex, real-world problem solving process, Figure 2 illustrates how information feedback regarding a complex, real-world problem affects the problem solving process, decisions, and the underlying mental model. As the mental model changes, the structure, strategy and rules of the competence system will change along with it, which in turn will change the problem solving process and decisions. Consequently, the same information transforms the problem solving process not only directly but also indirectly by changing the mental model and adapting the competence system.

FIGURE 2
Competence acquisition as double-loop learning (based on Sterman, 2000: 19; Argyris, 1985)



To summarize, competences consist of the agent's abilities, knowledge, and skills applied in a real-world setting and they depend on specific underlying mental models as well as on the environment's distinct features. *Mental models are theories about the real world based on the agent's sensation, perception, reasoning, attention, emotions, motivation, experiences, memory, values, norms, and creative imagination.* Via double-loop learning, competences enable the development of problem-specific behaviors suitable for dealing with complex non-standardized problems (see Figure 1).

EXISTING COMPETENCE/COMPETENCY FRAMEWORKS: A COMPARISON

Most existing classification schemes consist of three or four, and in some cases, five dimensions. Three-dimensional schemes usually include *professional*, *methodological*, and *social competences* (e.g., Faix & Laier, 1996 consider personal competence to be included within social competence); others, such as the three-dimensional scheme of the United National Industrial Development Organization's (UNIDO) consist of *managerial, generic, and technical/functional competencies* (UNIDO, 2002). Some four-dimensional schemes add *personal competence* and/or *action and activity competence* as own dimensions to *professional*, *methodological*, and *social competences* (Heyse & Erpenbeck, 2004; Kauffeld & Grote, 2000: 30-37; Kauffeld et al., 2000: 213, 217). An example for a five-dimensional framework is a recently developed and primarily in the sustainability field used framework, which includes *systems thinking*, *interpersonal*, *anticipatory*, *strategic*, and *normative competence* (Wiek et al., 2011).

TABLE 1

Competences/competencies frameworks – an overview (in alphabetical order)

Author/s (alphabet.)	Public. year/s	Framework approach (behavioral, functional, or a mix of both)	Applicability of the framework (general or specific)	Number of dimensions/ clusters incl. in framework	Type of dimensions*					Number of items by dimension
					Dimension 1	Dimension 2	Dimension 3	Dimension 4	Others	
Boyatzis	1982 2001	Behavioral	General comp.	3 clusters on abilities + 1 cluster of knowledge areas + 1 cluster of value themes	Goal and action management abilities	People management abilities	Analytic reasoning abilities	(Knowledge areas)	(Value themes)	6*8*8*(11*4)
Boyatzis	2008 2009	Behavioral	General comp.	3	Emotional intelligence competencies	Social intelligence competencies	Cognitive intelligence competencies			5*7*2
Dixon, Meier, Brown, & Custer	2005		Entrepreneurial competences	8 clusters	Team leadership	Communication skills	Perception of trustworthiness	Planning and organizational skills	Basic business skills; problem solving skills; communication skills; personal traits; creativity	10*7*7*8* 7*7*12*8
Epstein, Schmidt, & Warfel (Epstein Creativity Competencies Inventory for Individuals)	2008	Behavioral	Creativity comp.	4	Capturing	Challenging	Broadening	Surrounding		
Faix & Laier	1996	Functional	General comp.	3	Domain competence ('Fach-kompetenz')	Method competence ('Methoden-kompetenz')	Social competence ('Sozial-kompetenz')			
Heyse & Erpenbeck	2004	Mix	General comp.	4	Domain and method competence ('Fach- und Methoden-kompetenz')	Social-communicative competence ('Sozial-kommunikative Kompetenz')	Activity and action competence ('Aktivitäts- und Handlungs-kompetenz')	Personal competence ('Personaler Kompetenz')		16*16*16*16
Inyang & Enuoh	2009	Functional	Entrepreneurial competences	9	Time management	Communication	Human Resource Management (HRM)	Marketing management	Business ethics; social responsibility; leadership; decision-making; & financial management	
Kauffeld, Grote, & Frieling (Kasseler-Kompetenz-Raster)	2000	Functional	General comp.	4	Domain competence ('Fach-kompetenz')	Method competence ('Methoden-kompetenz')	Social competence ('Sozial-kompetenz')	Personal Competence ('Selbst-kompetenz')		11*12*13*9
Man & Chan	2002	Behavioral	Entrepreneurial competencies	6	Opportunity competencies	Relationship competencies	Conceptual competencies	Organizing competencies	Strategic competencies; commitment competencies	
McClelland, 1998; Spencer & Spencer, 1993; Boyatzis, 1982 (Behavioral-Event Interviews (BEI))	1982 1993 1998	Behavioral	General comp. (for managerial success)	12	Achievement orientation	Analytical thinking	Conceptual (inductive) thinking	Developing others	Flexibility; impact and influence; information seeking; initiative; interpersonal understanding; organizational awareness; self-confidence; team leadership	
Sipos, Battisti, & Grimm (Learning objectives for transformative sustainability learning (TSL))	2008	Mix	Comp. in sustainability	3	Head	Hands	Heart			6*6*6
United Nations Industrial Development Organization (UNIDO Competency model)	2002	Mix	Comp. within the UNIDO	3	Managerial competencies	Generic competencies	Technical & functional competencies			14*14*14
Virtanen	2000	Mix	Comp. of public managers	5	Task competence	Professional competence in substantive policy field	Professional competence in administration	Political competence	Ethical competence	
Wiek, Withycombe, & Redman	2011	Mix	Comp. in sustainability	5	Systems thinking competence	Anticipatory competence	Normative competence	Strategic competence	Interpersonal competence	

* In case of originally German terminology, the German terminology is added in ('_').

Main *peculiarities* and *shortcomings* of existing competences frameworks and inventories with respect to complex, real-world problem solving competences are summarized below (see also Table 1): (i) Differences between *European* and *U.S.* notion of competence/competency and related frameworks (e.g., Erpenbeck & von Rosenstiel, 2007 as European scholars, versus, e.g., Boyatzis, 1982, 2001 as U.S. scholar). (ii) Confusion and inconsistencies in the use of

the terms *competence* and *competency* (e.g., McClelland, 1973 versus McClelland, 1998; Snyder & Ebeling, 1992; Horton, 2000; OECD, 2005; Draganidis & Mentzas, 2006; Inyang & Enuoh, 2009; Chin-Cheh et al., 2011: 1123). (iii) Imprecise, improper or inconsistent use of the concepts of *knowledge, abilities, skills,* and *qualifications* in relation to or within *competences/competencies* (e.g., CEDEFOP, 2011). (iv) *Overlap* of categories; methodological competences, for example, might play a crucial role in other competence dimensions (e.g., Heyse & Erpenbeck, 2004; Kauffeld & Grote, 2000; Kauffeld et al., 2000; Faix & Laier, 1996). (v.) Insufficient potential of most currently used competence/competency frameworks to deal with the *increased complexity* of real-world problems *holistically*, i.e., using a *systems thinking* approach. Exceptions are sustainability-related frameworks; a comprehensive overview of these frameworks is given by Wiek et al., 2011. Boyatzis includes systems thinking in his competence framework as part of the dimensions "analytic reasoning abilities" (2001: 307) and "cognitive competencies" (2009: 754 f.). Alternatively, Sipos, Battisti, & Grimm, 2008, incorporate systems thinking as a learning objective in their framework. (vi.) Underrepresentation or lack of capabilities that are closely linked to dealing with complex real-world problems, for example *creativity* as a prerequisite of innovation, both of which represent essential ingredients for crises resolution (exceptions are provided by e.g., Epstein et al., 2008; Sipos et al., 2008); and *sociocultural* (collaborative respectively inter-personal) *competences* including inter- and transdisciplinarity (exceptions are provided by e.g., Sipos et al., 2008; Getha-Taylor, 2008; Wiek et al., 2011). In essence, since a common theoretical background, consistent terminology, and definitions of competence are missing, we currently lack clear, commonly agreed-upon competence frameworks.

The four core objectives of a new competence framework introduced in the following section are to: (1) provide a clear competence terminology; (2) outline the role of abilities, knowledge, and skills across all competences (see Figure 1); (3) consider the influence of mental models in conjunction with the environment (see Figure 1); and (4) delineate additional competences needed, apart from personal competence and professional domain competence, to systemically, creatively, and collaboratively address complex real-world problems.

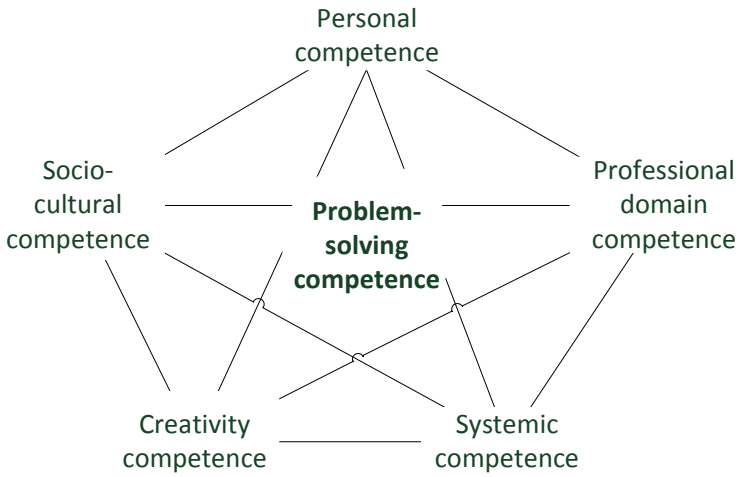
A NEW COMPTENCE FRAMEWORK FOR INNOVATION AND SUSTAINABILITY

The following concept provides a new competence framework to address complex real-world problems. This *framework of problem-solving competence* focuses on the previously outlined peculiarities of complex real-world problems and the competences needed to solve them. It differs from most other approaches (see Table 1), which primarily focus on behavioral aspects or on job or domain requirements. Here, I suggest that *problem solving competence* for complex real-world problems depends on the synergetic interaction of personal competence, professional domain competence, systemic competence, creativity competence, and sociocultural (collaborative) competence (see Figure 3): (1) *personal competence* – to be aware of, and manage oneself within, the problem solving process and to develop one's personality; (2) *professional domain competence* – needed to comprehend the peculiarities of the specific domain in which the problem is embedded (e.g., in order to develop a public health strategy for Haiti, political, medical, social, and cultural expertise is needed); (3) *systemic competence* – needed to understand and appropriately affect the entire system and all its intra- and interdependencies (e.g., Scholz, 2011; Kegan, 1994; Kegan & Lahey, 2009; Wiek et al., 2011; Steiner, 2011); (4) *creativity competence* – to be capable of "stepping outside" of old habits and synthesize convergent and divergent thinking in order to create something new or find a new solution to complex real-world problems such as crises (e.g., Steiner, 2011; Epstein et al., 2008; Sipos et al., 2008); (5) *sociocultural (collaborative) competence* – needed for collaboration between various disciplines but also to enable joint problem solving in the interplay of science and society (e.g., Sipos et al., 2008; Getha-Taylor, 2008; Wiek et al., 2011). When dealing with complex challenges such as crises or sustainability on a global scale, the integration of cultural and global requirements becomes even more crucial (e.g., Rice, 2007; Mansilla & Jackson, 2011; Reimers, 2009). The need for an extended set of competences is highlighted by the fact that crises as well as innovation (and their interplay), due to their dynamic behavior, most probably cannot be addressed without them. For example, while a single problem solver might lack the required competences to successfully deal with a problem, other members of the collaborative entity might provide those missing capabilities – hence, the collaborative entity such as a group or a network might be successful even if the individual would have failed.

Consequently, to address a complex real-world problem such as a crisis, one needs to enhance competences within a complex system by focusing on (1) the development of an individual's competences and (2) on the proper constellation of a collaborative system, since they, together, provide the overall set of competences. Importantly, one competence can usually not be substituted by another; such a substitution might lead to suboptimal solutions or failure.

FIGURE 3

A new conceptual competence framework for solving complex real-world problems



As opposed to most European frameworks (e.g., CEDEFOP, 2011; Heyse & Erpenbeck, 2004; Faix & Laier, 1996), the new competence framework does not consider *methodological competence* as an own dimension. It has historically been difficult to cluster methodological capabilities (particularly related to skills and knowledge) into a single competence dimension; moreover, in my view, methodological capabilities including appropriate methods are required across all five competence dimensions (i.e., personal, professional domain, systemic, creativity, and sociocultural competence; see Figure 3). All five competence dimensions specified in this new conceptual framework for solving real-world problems interact synergistically as one joint holistic system, which can be referred to as *problem solving competence;* problem solving competence profiles of the individual and of the collaborative entity will vary, depending on the specific requirements each real-world problem poses. In the following, specific traits of all five competence dimensions are described in greater detail:

1. *Personal competence*: The capability to be aware of and manage oneself within the problem solving process (and within collaborations), for self-reflection as part of personality development, to comprehend mental models that underlie one's own thinking (including e.g., values and norms – see Figure 1), to think in a goal- and future-oriented manner, to be self-motivated, to act self-dependent, and to be able to apply supportive methodological capabilities. Hence, personal competence enables individuals (problem solvers) to develop their own personality as a prerequisite for sociocultural (collaborative) competence. Personal competence has been considered by European scholars in various constellations (e.g., Heyse & Erpenbeck, 2004; Kauffeld & Grote, 2000; Kauffeld et al., 2000; and Faix & Laier, 1996), whereas U.S. scholars have mainly considered it within their behavioral dimension related to *competencies* (as opposed to competences) (e.g., Boyatzis, 1982, 2001, 2007; McClelland, 1973, 1998).
2. *Professional domain competence:* A specific problem is always related to certain domain-specific knowledge, skills, and methods (e.g., the domain of transport systems when working on mobility innovations), which are predominantly acquired by means of education (including vocational training). In contrast to the other four competence dimensions, this competence dimension focuses on *specific* disciplines or domains. Other terms which have been used instead of professional domain competence are domain competence, subject competence, or – in German – "Fachkompetenz" (e.g., Heyse & Erpenbeck, 2004; Kauffeld & Grote, 2000; Kauffeld et al., 2000; and Faix & Laier, 1996). Despite the growing demand for systems thinking in our globalized world, developing professional domain competence still remains the core objective of most educational programs.
3. *Systemic competence:* Systems thinking as the capability to understand core characteristics and general patterns of a complex system (i.e., its borders, the interrelatedness of its elements, its interaction with its environment, and its dynamic behavior over time, based on the peculiarities of the underlying mental models employed) and the capability to choose and apply appropriate methods for modeling a current complex system and its potential future paths of development. Methods that are being used can be either qualitative, such as graphical causal-loops diagrams, or quantitative, such as stock and flow diagrams, as applied within or in conjunction with system dynamics. Furthermore, systemic competence aims to develop and analyze future scenarios under consideration of historical development. For example, the transition of a socioeconomic system might be illuminated by systemic competence. The term *systemic* is not used synonymously with *systems thinking*, but rather as a meta-concept that

includes systems thinking. Forrester (2009: 21), for example, points out that systems thinking refers to "thinking about systems, talking about the characteristics of systems, acknowledging that systems are important, discussing some of the insights from system archetypes, and relating the experiences people have with systems" yet "it is not more than five percent of a systems education," and he calls for participative activities such as active learning which can produce changes in mental models. Other scholars (e.g., Meadows, 2008) consider systems thinking as a comprehensive concept that may range from 'natural systems thinking' (i.e., holistic thinking without the need for sophisticated methods) to computer-based simulations. No other competence framework has used systemic competence, and only few have considered systems thinking, for example frameworks within the sustainability field (see overview in Wiek et al., 2011; Sipos et al., 2008). General management and human resource development do not include systems thinking as core dimensions in their frameworks. For example, the five meta-dimensions within Boyatzis' (1982, 2001) model of management are goal and action management abilities, people management abilities, analytic reasoning abilities, knowledge areas, and value themes. In his model, systems thinking is only one of eight analytic reasoning abilities.

4. *Creativity competence:* In the here proposed new competence framework, creativity is not considered an ability or personality trait, but rather a competence that can be developed and trained through creativity techniques applied in real-world settings (Steiner, 2011). Such techniques include individual and group-specific methods for creative problem solving and team analysis, amongst others. Therefore, creativity is a competence needed to generate original outcomes (e.g., solutions for a specific problem or process related improvements) that go beyond routine problem solving and already known solutions (Steiner, 2011: 17; Epstein et al., 2008). As Simonton (2003: 320) points out, creativity must be viewed as a complex phenomenon "that occurs at multiple levels, from individuals, interpersonal interactions and problem solving groups to cultures, nations, and civilizations." Similar to systemic competence, only few competence frameworks have previously considered (or even mentioned) creativity, with few exceptions (e.g., Halbesleben, Novicevic, Harvey, & Buckley, 2003; Sipos et al., 2008).
5. *Sociocultural (collaborative) competence:* Recent global crises highlight a *lack of capabilities for collaborative problem solving* in our highly interrelated and complex world (e.g., Gabellone, 2011; PWC & Atlantic Council, 2011). Complex real-world problems call for innovation in general, and citizen-driven innovation in particular. They increasingly depend on *collaborative effort*, which is more than just the aggregate of individual performances. The collaborative nature of most complex problem solving processes becomes obvious not only in the various communication and interaction processes among academic disciplines (i.e. interdisciplinarity), but also between academics and society respectively, between experts and various stakeholder groups (transdisciplinarity) (Scholz, 2012; Steiner, 2011; Scholz & Tietje, 2002). There is also a need to teach inter- and transdisciplinarity in higher and professional education (the latter also known as VTE, vocational training and education) as well as in the larger context of national and international innovation systems (e.g., Lundvall, 2010: 329 f.; Lundvall, Johnson, Andersen, & Dalum, 2002). Sociocultural (collaborative) competence builds on team-, integration-, reflection-, and conflict-specific capabilities, and the willingness and capability for appreciative interaction among the involved problem solvers as the basis for any collaborative *inter- and transdisciplinary* problem solving process. In any problem solving process, it is therefore essential for individual and teams of problem solvers as well as other stakeholders to establish a joint system of objectives (Steiner, 2008, 2009). Key questions to ask are: What are the required competences in order to succeed, and how can each individual involved improve their competences to maximize their contribution? *Cultural competence* as the capability to deal with various cultural settings (Hampden-Turner & Trompenaars, 2000; Dana & Allen, 2009), is a subcategory of *social competence* (e.g., Boyatzis, 2008, 2009; Kauffeld & Grote, 2000; Kauffeld et al., 2000; Faix & Laier, 1996). *Social competence* is the capability and willingness to communicate and collaborate with others, based on an (approximate) understanding of the preference profiles and emotional effects as well as of potential benefits and burdens for all other stakeholders. Together, the two constitute sociocultural competence. Further, *competences of a collaborative entity* (e.g., an interdisciplinary working group, transdisciplinary collaborations between science and society, a border-crossing collaboration between companies) are not just the sum of the individuals' competences. Instead, to comprehensively assess a group's competences and/or its dynamic behavior, several additional phenomena need to be considered. These include "groupthink" (according to Janis, 1982: 7 f., the desire for harmony within a group can interfere with realistic and logical reasoning), "group productivity" (according to Steiner, 1972, process losses can reduce the overall productivity of the group), "principle of non-summativity" (according to Rathunde, 1999, the whole system is greater than the sum of its parts); and "equifinality" (according to Bertalanffy, 1998, various paths can lead to the same goal).

CONCLUDING REMARKS

In this paper, systemic, creativity, and sociocultural (collaborative) competences are considered crucial in complementing personal and professional domain competences to tackle today's complex real-world challenges. Furthermore, complexity is here not considered just a burden to be dealt with in the problem solving process, but a tremendous opportunity to create innovative solutions based on the provision of appropriate competences of the problem solvers. The peculiarities of collaborative competences of groups, organizations, regions, nations, and beyond should be studied. Finally, to further operationalize the here proposed five core competence dimensions, they need to be measured by comprehensive indicator sets.

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